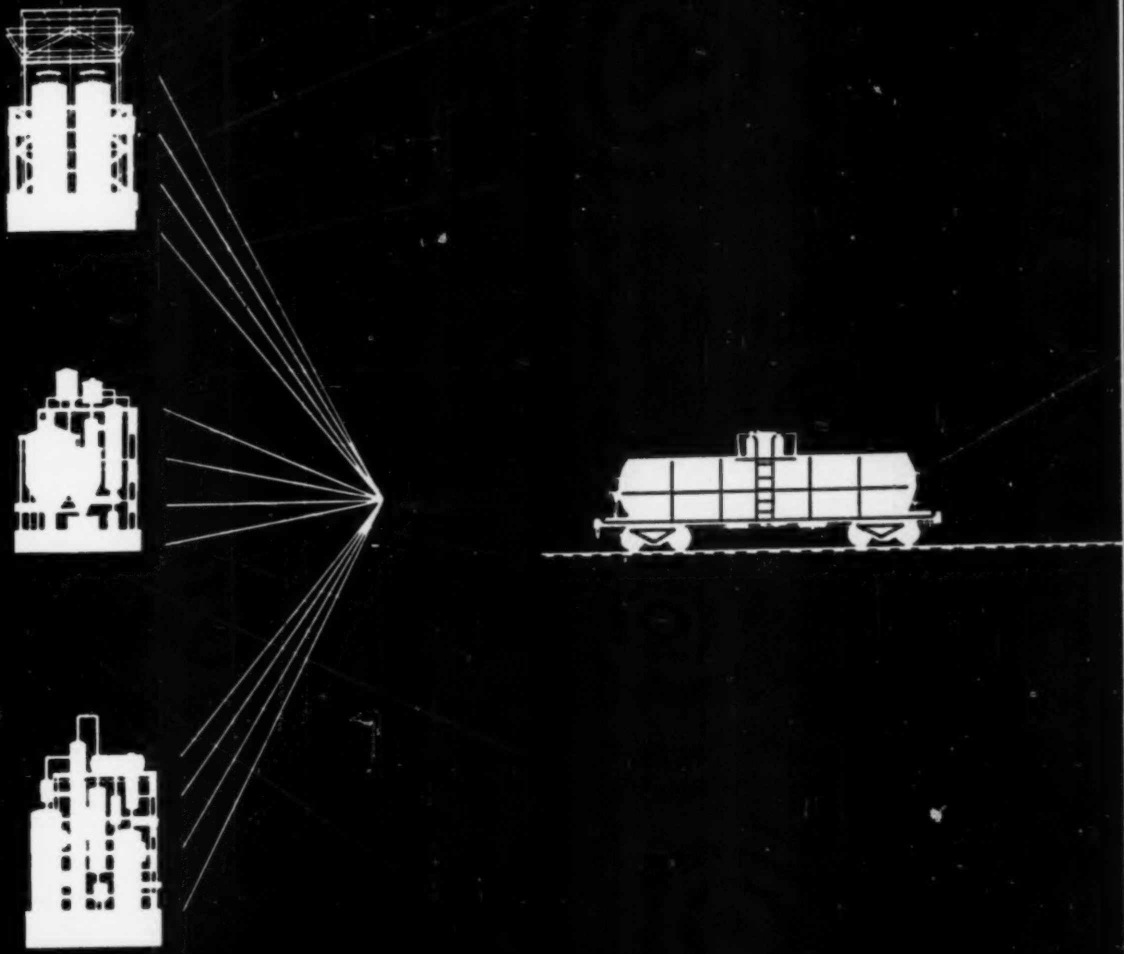
Chemical Engineering Progress

APRIL 1954



PRODUCTIVITY

measurement and control

Chemical Engineering Progress

APRIL, 1954

Volume 50, No. 4

Editor: F. J. Van Antwerpen

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Advertising Manager: L. T. Dupree

THIS MONTH'S COVER

Productivity to a chemical engineer is almost certain to entail charts, processing units, and tank cars. The proper relationship between these and other factors involved, is treated in two articles: one on measurement and control (page 167) and other factors involved is particularly to the chemical industry (page 173).

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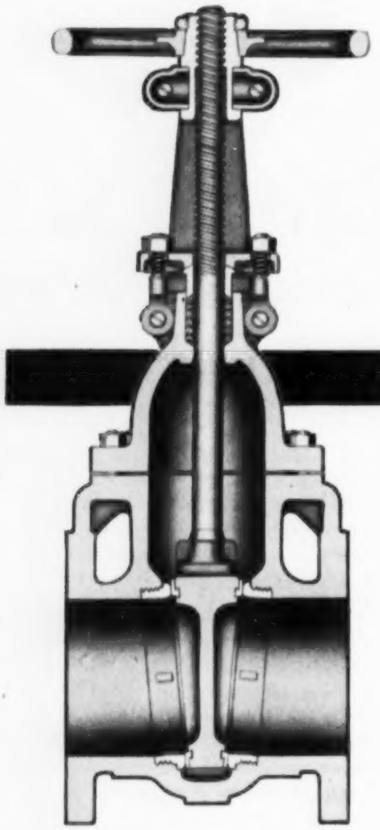

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WORKING PRESSURES: 200 pounds cold water, oil, or gas, non-shock.
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In the *Petroleum* industry, these valves are giving outstanding service on oils with traces of mineral acids . . . in *Wood Treating*, on creosote vapors and oils . . . in *Pulp and Paper* processing, on alkaline liquors of various kinds. In fact, No. 14477 valves are ideal for mildly corrosive services where all-iron valves are inadequate but where it is uneconomical to use all-stainless steel valves.

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CHEMICAL PROCESS NEWS

PUBLISHED BY CHEMICAL PROCESS DIVISION, THE M. W. KELLOGG COMPANY APRIL 1954

NOTES ON

PHTHALIC ANHYDRIDE

Of interest to chemical processors in general, and particularly in the United States where the irregularity of supply of naphthalene has hampered the production of phthalic anhydride, is the development of a new feed-preparation step in Kellogg's laboratories which permits the use of low-grade, sulfur-containing naphthalene in the Fluid phthalic anhydride process.

* * *

This step in effect increases the supply of feed available for the Fluid process with its recognized advantages over conventional methods: higher yields . . . lower initial cost . . . easier handling of catalyst . . . longer catalyst life . . . increased safety through better control of heat.

* * *

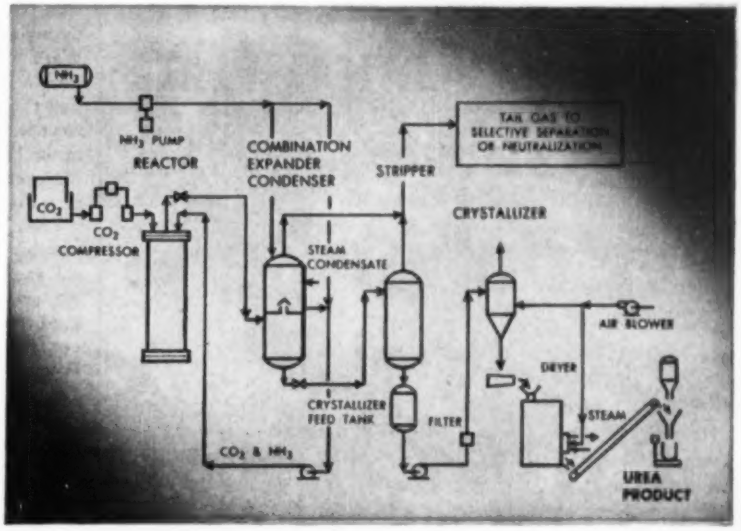
Meanwhile several design improvements are incorporated in new Fluid phthalic plants designed and now being erected by Kellogg. When these units are completed they will produce about 50 million pounds of phthalic annually.

* * *

While the basic chemistry involved in the oxidation of naphthalene in the presence of a catalyst is well known to chemical manufacturers, new developments in the process for this chemical have not been extensively publicized.

* * *

One of these is an improved condensing system which may be included under certain circumstances. This not only reduces capital investment but also improves actual operating conditions. It precludes, for example, the need for operators to come in direct contact with the phthalic or its fumes.



Montecatini Process Produces Higher Quality Urea at Lower Investment

The new low-cost method of producing synthetic urea of exceptional purity developed by Montecatini—well-known Italian firm—is shown in the flowsheet above.

Kellogg is the exclusive licensor of the process, a method which reflects more than 30 years of experience in nitrogen chemistry.

One of the most important features of the Montecatini process is virtual elimination of corrosion problems generally associated with urea synthesis. This is accomplished not only through careful selection of materials but also through maintaining a high concentration of ammonia which tends to curb corrosion. Furthermore, relatively mild conditions are employed in the reaction zone in comparison with other urea processes, thus further limiting corrosion.

As a result of these factors, considerable costly alloy equipment is eliminated from many parts of the plant and maintenance expense is held at a minimum.

In addition to these factors affecting the costs of plant and operation it is also of interest that the process produces resin-grade urea without the additional expense of special purification steps. An aqueous solution of 5% urea from a Montecatini plant is clear and colorless, a difficult specification to meet and one which is particularly important for plastics manufacture. A low biuret content of less than 0.01 wt.% is also obtained.

From the standpoint of using the urea as a feed supplement, it is also of importance that no lead-lined equipment is employed in the process, eliminating the possibility of lead toxicity.

For further information, technical data, etc., relating to chemical or petrochemical processing, write

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LETTERS TO THE EDITOR

Engineers Can Write Better German

After reading the first part of "Engineers Can Write Better" in the February '54 issue of Chem. Eng. Progress I leafed through the magazine to the section on the Washington meeting. On page 68*A*, in the paragraph "Tips for Gourmets" I found something that was in complete disagreement with the principles and ideas set forth in the better writing article. You speak of "Hammel's for wiener schnitzel and good draught beer in a gemütlich atmosphere."

While the correct form gemütlichen atmosphere would probably be too much to ask for, perhaps a compromise could be reached in a form that would read a little better and be closer to the correct form—i.e., gemütliche atmosphere. Most of our fellow chemical engineers have probably forgotten their German grammar and passed over this incongruity without noticing it but I just couldn't resist the temptation to comment on it.

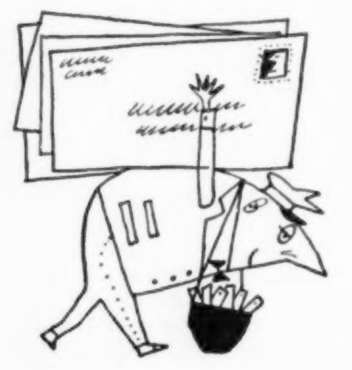
Otto Pfefferkorn
Philadelphia, Pa.

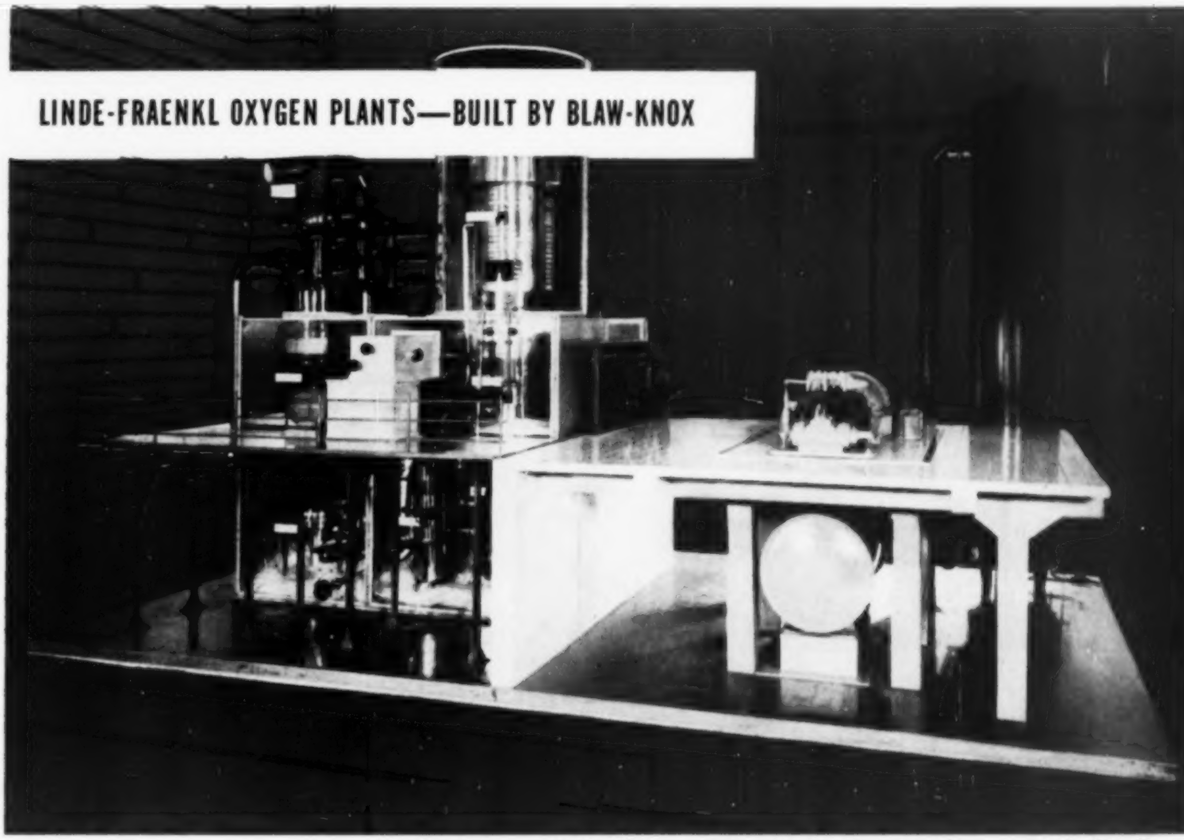
Noah Webster allows gemütlich.—*Ed.*

A Defense of the Army

In the March issue of Chemical Engineering Progress, a letter appeared entitled "An Old Army Game." This letter points out that eligibility for participation in the Scientific and Professional Program (SPP) of the Army requires one year of experience for chemical engineers but none for mechanical engineers or electrical engineers. It is true that no experience is required of electrical engineers. However, according to Department of the Army Special Regulation No. 615-25-11, a mechanical engineer must possess either one year of professional experience or an M.S. degree to be eligible for this program. The requirements for participation in the SPP Program in a given technical field do vary from time to time in accordance with the

(*Continued on page* 10)





LETTERS TO THE EDITOR

(*Continued from page 6*)

needs of the Army for technical personnel in that field. There is also a considerable variation in the requirements for participation in the program among the various professional fields. This is due not to "An Old Army Game" as Mr. Lubitz has suggested, but rather to the fact that the Army is no different from any large industrial organization in that it must gear the minimum requirements for participation in any technical field of the SPP Program to its needs for technical personnel in that field.

This program is not perfect, but it has come a long way toward providing an opportunity for technical men to continue their professional careers during Army duty.

Irving Leibson
Anthony G. Cacoso
Frederick, Md.

The heading "An Old Army Game?" originated in this office. Note the question mark as run with the title.—*Ed.*

I note in the A.I.Ch.E. Notes and News of the February number of Chemical Engineering Progress that you report that the Philadelphia-Wilmington Section of A.I.Ch.E. led in the membership drive last year. This is not in agreement with the final report of the Membership Committee chairman for 1953. His report of January 15, 1954, indicates that the South Texas Section again secured more members than the Philadelphia-Wilmington Section. I would appreciate your investigating this matter and making appropriate corrections of explanations.

J. T. Moody
Chairman, Membership Committee,
South Texas Section, A.I.Ch.E.

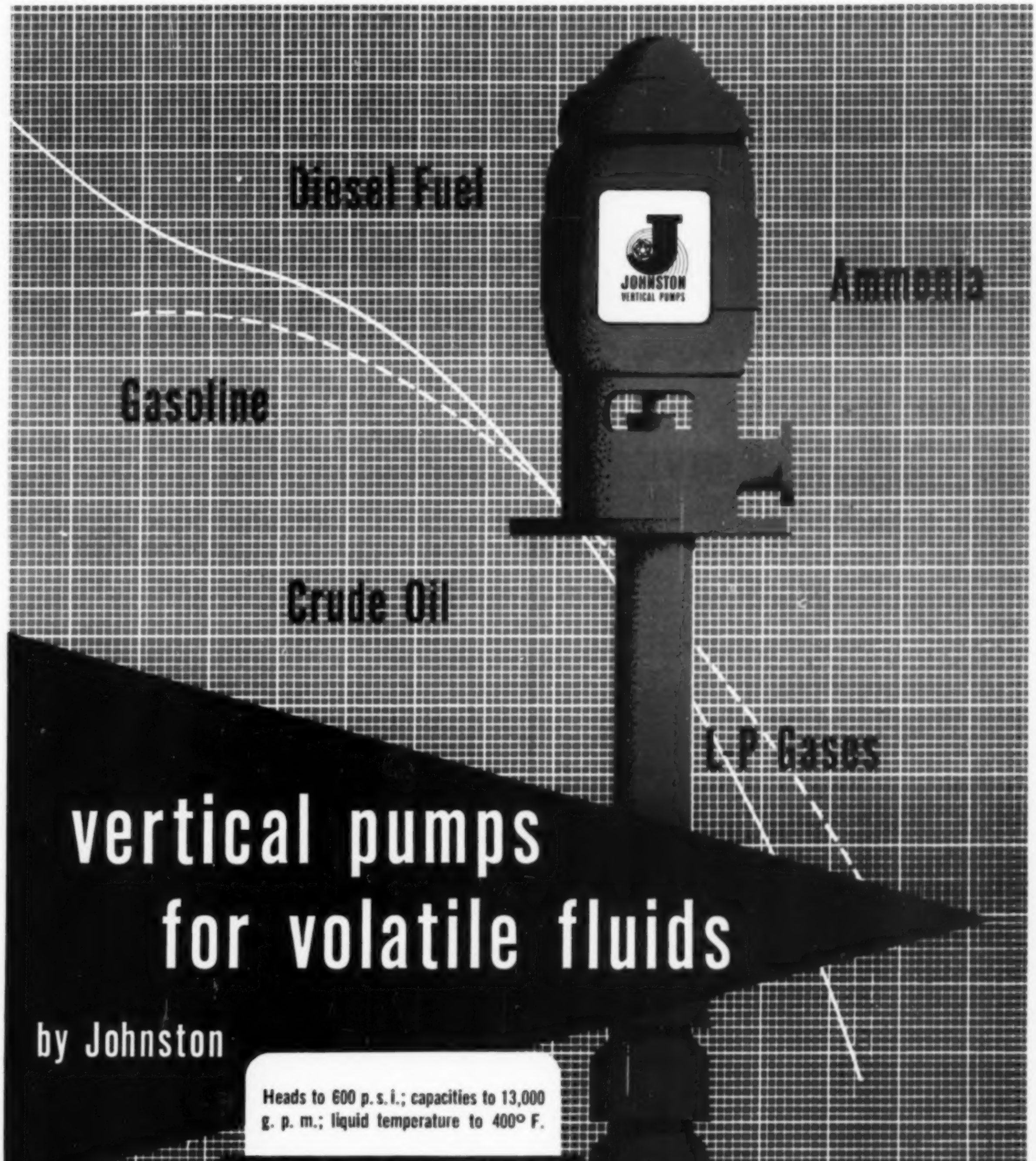
We flubbed.

Annual report was quoted, which included returns to November 1. In final two months of year (1953) South Texas soared ahead, to a total of 80 against Philadelphia-Wilmington's 74. Congratulations, Texans!—*Ed.*

A Definitive Paper

I was very interested to read "A Correlation of Flooding Velocities in Packed Columns" by Hoffing and Lockhart in the February issue. It seems to take care of this subject for quite a few years.

M. C. Molstad
Director, Dept. of Chemical Engineering
University of Pennsylvania
Philadelphia, Pennsylvania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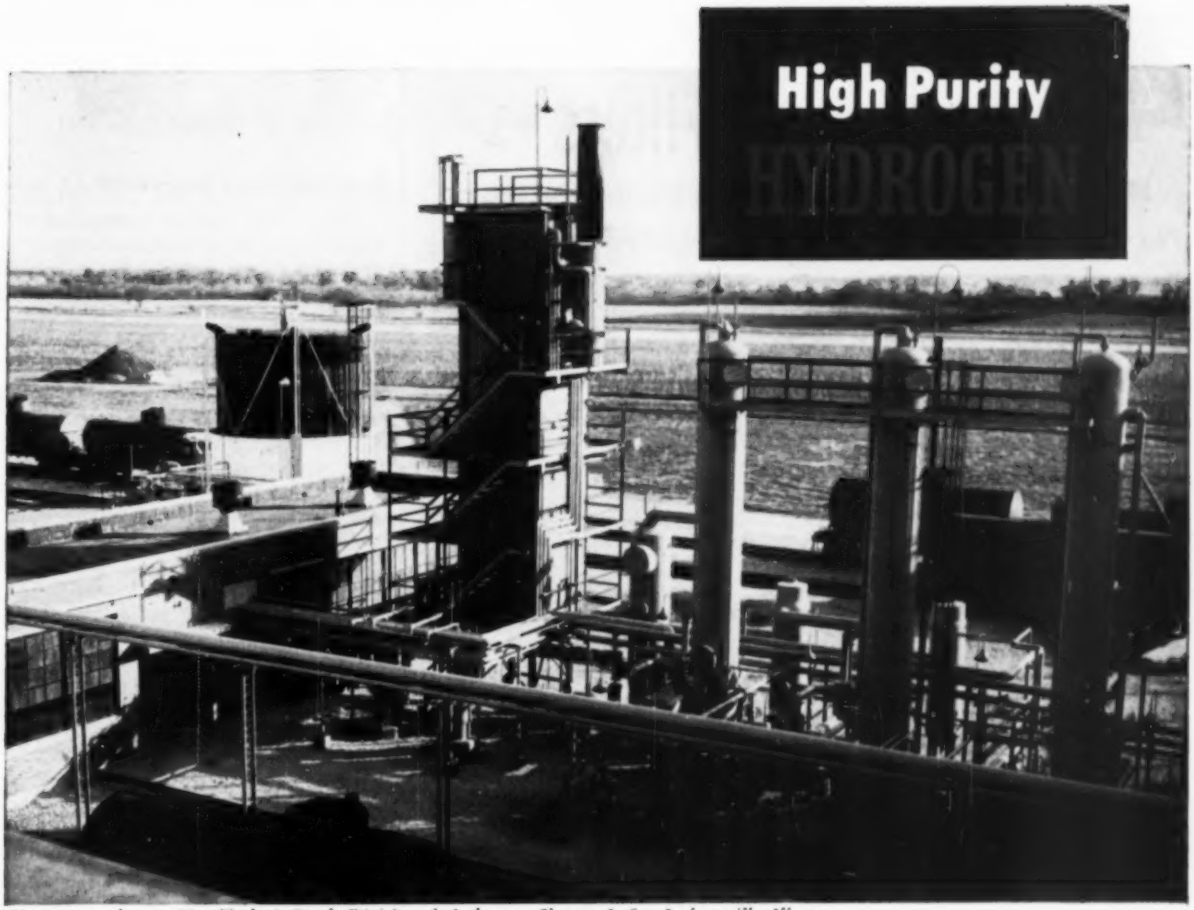

HYGIRTOL plant at Mrs. Tucker's Foods Division of Anderson, Clayton & Co., Jacksonville, Ill.

Another GIRDLER plant for efficient hydrogen production

HIGH PURITY HYDROGEN is required on a continuous basis for large-scale edible oil processing such as at Mrs. Tucker's new plant. This is provided by the Girdler HYGIRTOL* plant shown above. It produces hydrogen exceeding 99.8% in purity, continuously. Operation of the plant is instrument-controlled, practically automatic, safe and clean.

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NOTED AND QUOTED

Now — Nuclear Engineers!

Before there can be widespread interest in providing nuclear engineering education, there must be a recognized demand—and some sort of a tag to place on the people who graduate from these courses.

This demand—and this tag—can be achieved by recognizing nuclear engineering as one of the specialized branches of engineering.

In my own mind I identify a nuclear engineer as one who has been given a good background in the fundamentals, and who has been given the usual training in an engineering specialty, such as electrical or chemical engineering. But in addition to that education, he has received a certain minimum training in the special considerations that must be given to atomic energy work.

L. E. Johnston
Atomic Energy Commission

Ave, Youth!

. . . Third, have faith in young engineers. Sometimes they accomplish astonishing results. Some of the newest areas of engineering endeavor—atomic energy, guided missiles, magnetic amplifiers—have been engineered entirely by young men. In these fields there practically are not any "old" engineers.

J. F. Peters
In *Electrical Engineering*

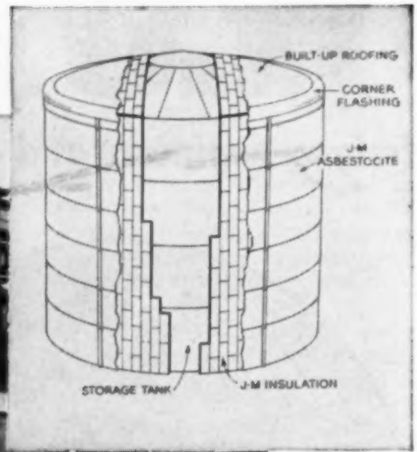
" . . . Saw the vision of the world and all the wonder that would be . . ."

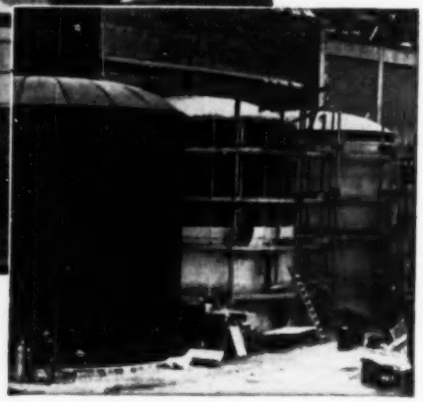
Whatever a man imagines he can attain, if he doesn't become too arrogant and encroach on the rights of the gods.

Is aviation too arrogant? I don't know. Sometimes, flying feels too god-like to be attained by man. Sometimes, the world from above seems too beautiful, too wonderful, too distant for human eyes to see, like a vision at the end of life forming a bridge to death. Can that be why so many pilots lose their lives? Is man encroaching on a forbidden realm? Is aviation dangerous because the sky was never meant for him? When one obtains too great a vision is there some power that draws one from mortal life forever? Will this power smite down pilot after pilot until man loses his will to fly? Or still worse, will it

(*Continued on page* 24)

Cutaway drawing shows how J-M *Weather-Protected* Insulation is applied to tanks such as those at the S. D. Warren Company paper mill. Standard methods for mechanical securement of the insulation are used. Asbestocite sheets are then applied over the insulation, in accordance with the simplified Johns-Manville specification.





▲ **(Above)** Completed job of J-M *Weather-Protected* Insulation on black liquor tanks of the S. D. Warren Company.

(Right) Skilled applicators of an outstanding J-M Insulation Contractor, P. S. Thorsen Co. of South Boston, Mass., applying Asbestocite sheets over Zerolite insulation. ▶

S. D. Warren Company saves fuel, reduces maintenance on outdoor tanks with J-M *Weather-Protected* Insulation

On black liquor tanks of the S. D. Warren Company paper mill at Cumberland Mills, Maine, Johns-Manville *Weather-Protected* Insulation pays a "double dividend":

It saves money on fuel and maintenance. J-M Zerolite* insulation keeps the heat in . . . thereby saving a substantial amount in fuel costs. J-M Asbestocite*, a strong asbestos-cement sheet material, covers the Zerolite Insulation to protect it both from the weather and from wetting due to normal plant operations. This "bodyguard" layer of Asbestocite Weather Protection makes the tanks virtually maintenance-free and helps hold down operating costs.

It helps provide close temperature control. The temperature of black liquor in these tanks must be maintained so that it will flow freely and not clog up pumping apparatus. J-M Weather-Protected Insulation helps do the job dependably and economically.

Whatever the operating temperature of outdoor tanks and vessels, Johns-Manville offers the right insulation for application under the Asbestocite weather protection. For example, J-M 85% Magnesia Insulation is also widely used for this service because of its proved performance for temperatures to 600 F.

To be sure that the insulation and its weather protection is properly applied to pay the greatest return on your investment, J-M offers the services of experienced J-M Insulation Engineers and J-M Insulation Contractors. These men stand ready to give you an insulation job that will more than pay off your initial investment through maximum fuel savings.

For further information about J-M Weather-Protected Insulation, write to Johns-Manville, Box 60, New York 16, New York. In Canada, 199 Bay Street, Toronto 1, Ontario.

*Reg. U. S. Pat. Off.

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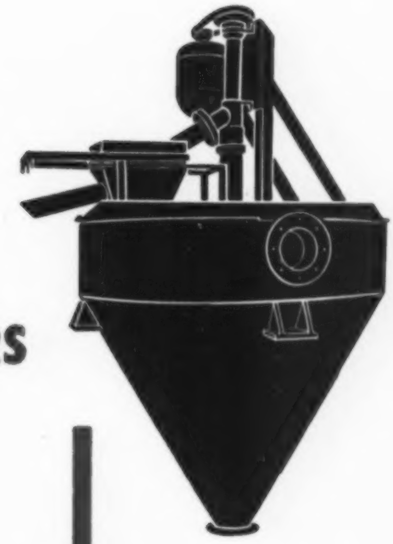

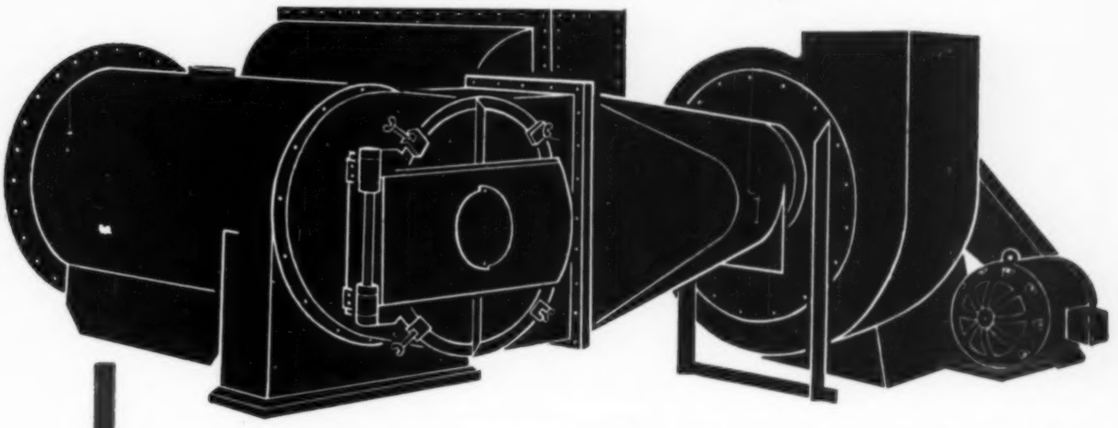

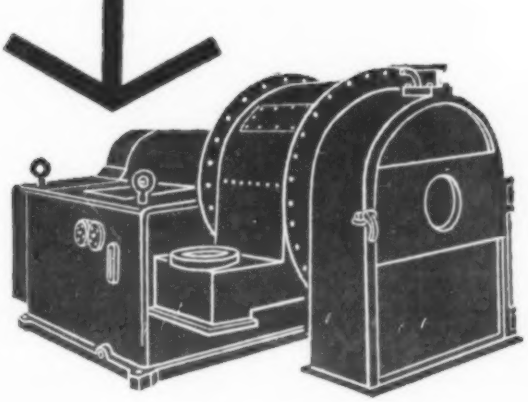

BAKER PERKINS Concentrating Screw Type Feeders, designed for use with continuous centrifugal installations, insure a uniform rate of feed to the centrifuge and increase the percentage of solids in the feed. The result: higher centrifugal efficiency, lower maintenance costs and greatly improved product quality.

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If your facilities already include a B-P Centrifugal, the Feeder and Dryer attachments will help speed up production, reduce your maintenance and operating costs, and improve the quality of your products.

Consult a B-P sales engineer or write us today for further information.

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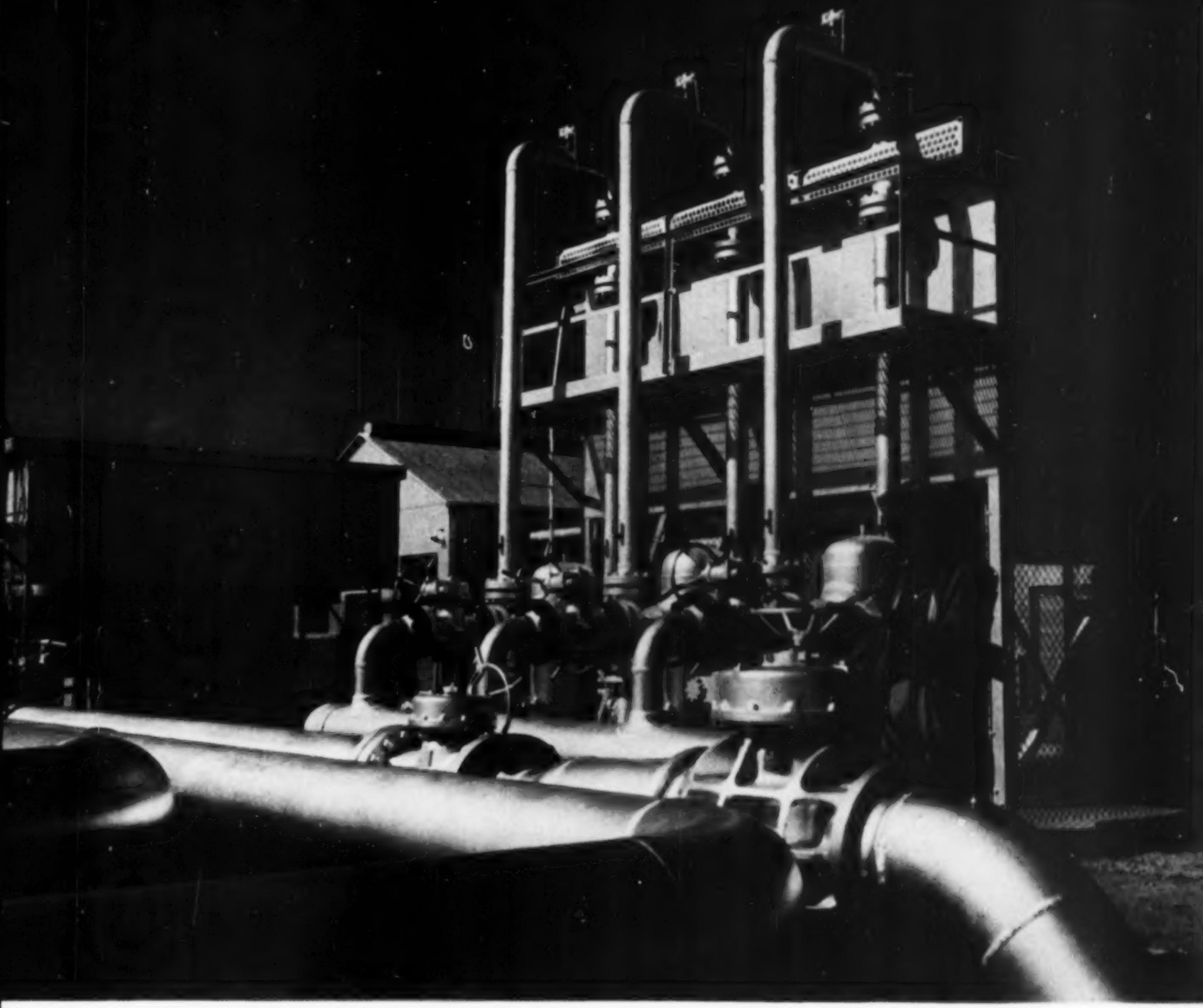

CONSTANT CONTROL FOR CONTINUOUS PROCESSES

Ever notice how many Rockwell-Nordstrom valves you see at key points in continuous operation processes—where failure of one valve can shut down an entire plant? There's a sound reason for that: Nordstrom valves have a reputation for *not* failing.

If it's wise to use Nordstrom valves in *tough* spots—in lines that must operate 24 hours a day, 365 days a year, year in, year out—doesn't it stand to reason they'll give better service in almost *any* spot?

Nordstrom's first costs are comparable to other valves. In the long run, they're invariably the best buy. There's no substitute for Rockwell experience. Use it to save money on valves. *Rockwell Manufacturing Company, Pittsburgh 8, Pa.*

THREE WAYS THE NORDSTROM LUBRICANT WORKS

Lubricant surrounds each valve port with a vapor tight pressurized seal. **Nordstrom valves stay tight.**

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NORDSTROM VALVES

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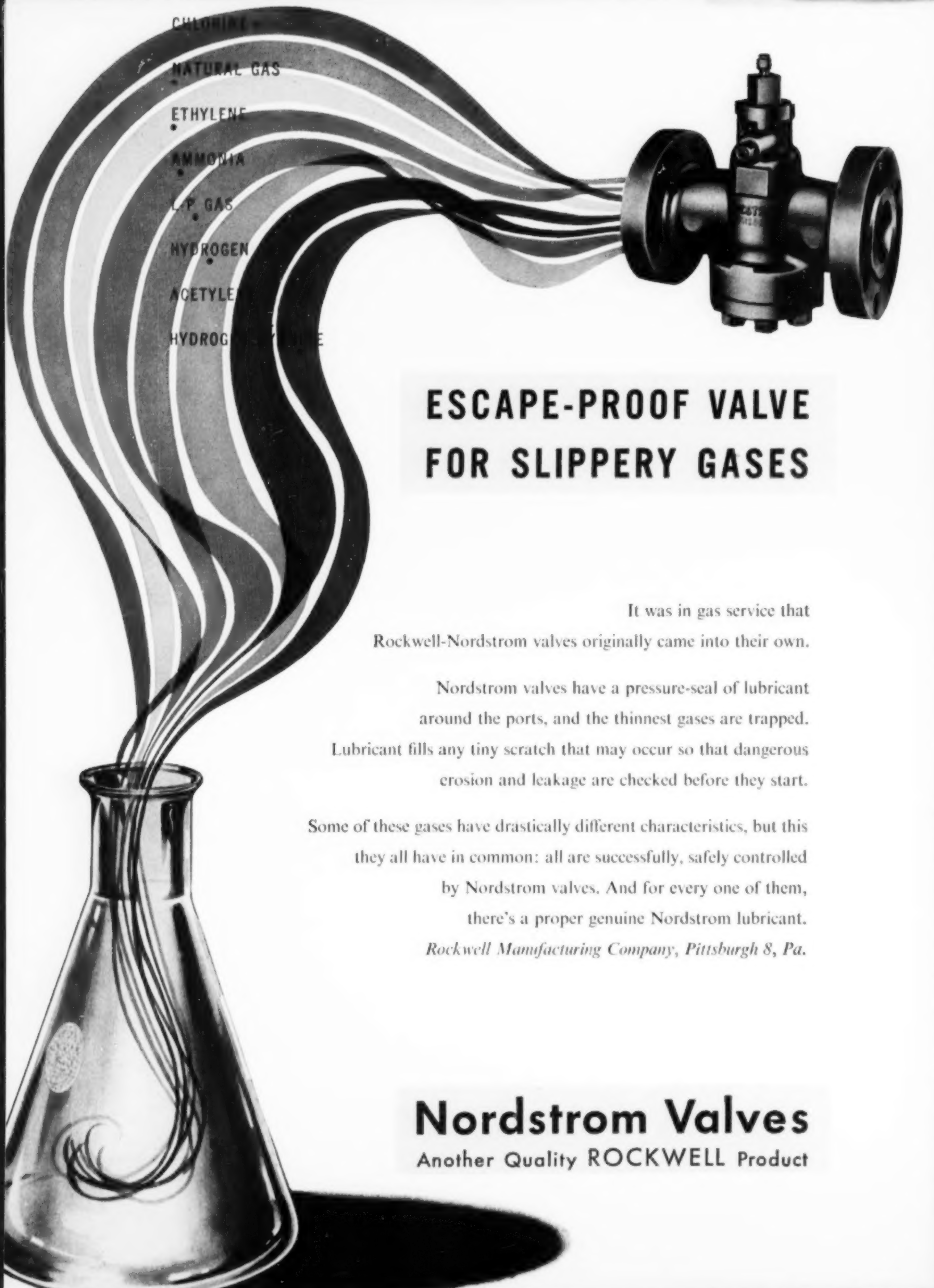
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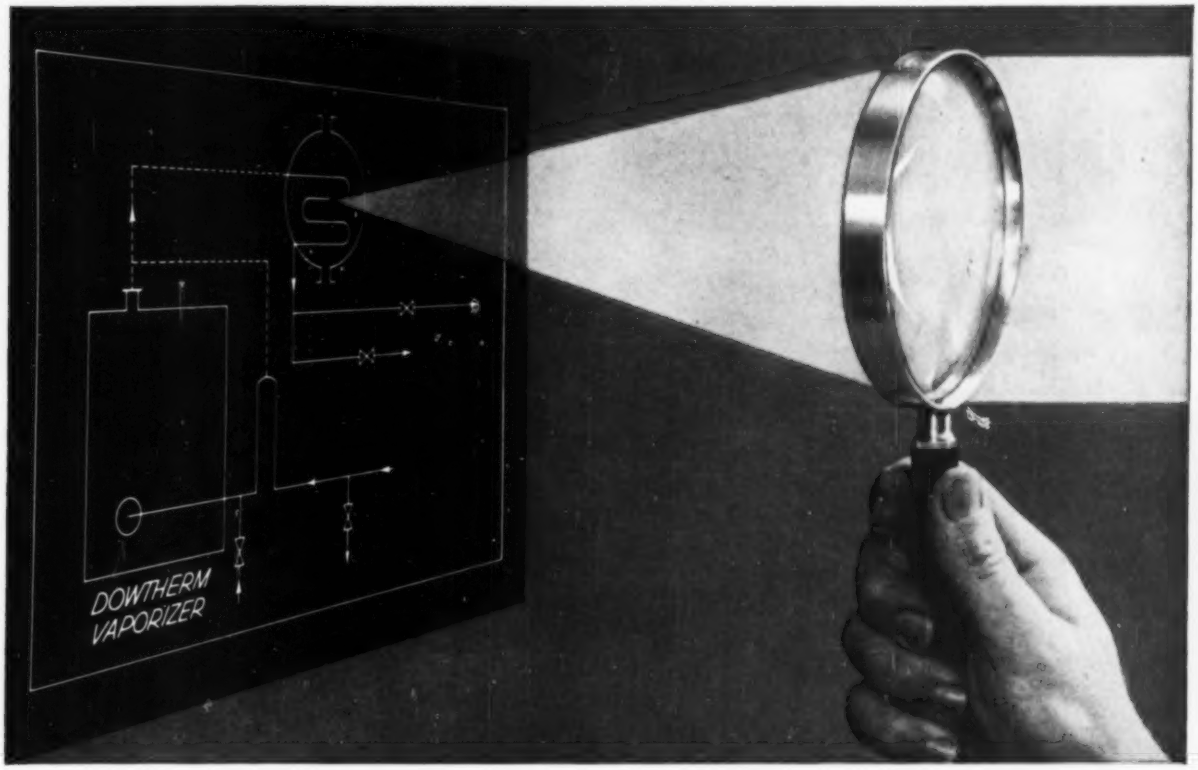

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CHEMICAL PROGRESS WEEK-MAY 17-22

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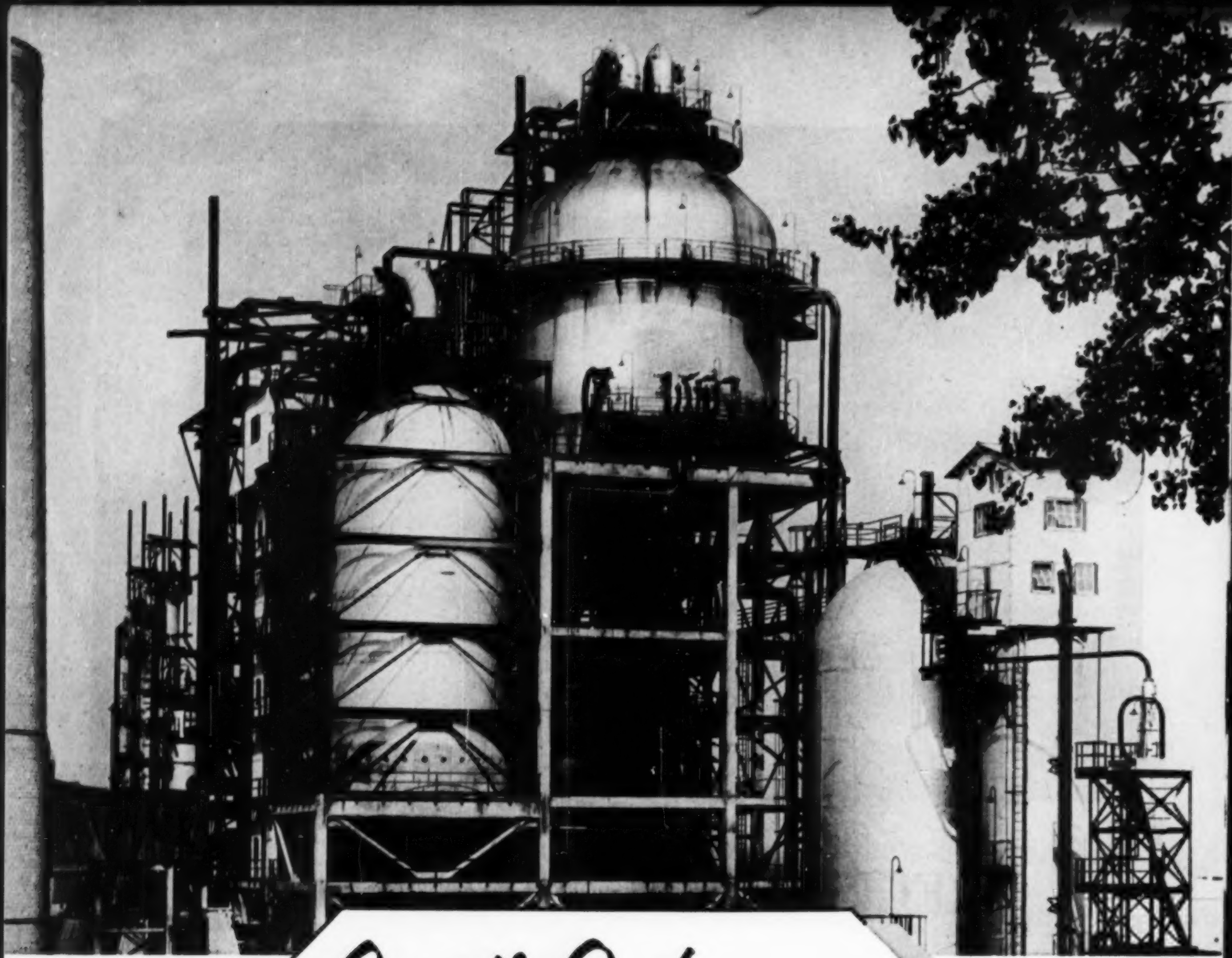

Photo Courtesy The Texas Company

NOTED AND QUOTED

(Continued from page 14)

deaden his senses and let him fly without the vision? In developing aviation, in making it a form of commerce, in replacing the wild freedom of danger with the civilized bonds of safety, must we give up this miracle of air? Will men fly through the sky in the future without seeing what I have seen, without feeling what I have felt? Is that true of all things we call human progress—do the gods retire as commerce and science advance? . . .

Charles A. Lindbergh
In "The Spirit of St. Louis"

The Rights of the Technicians

Of interest and importance is the statement of the appellate court that the testimony presented on behalf of the government of "highly skilled technicians from the cream of the technical chemical industry in the United States should be accorded greater weight than that of a professor, who is also a chemist, when none of his experience in the United States has been in the chemical industry."

R. W. Dill
Collector of Customs, New York
In speech at S.O.C.M.A.

Quintessence of Science—Revolution

Another feature of the scientific method, which perhaps has had some influence upon human evaluations, is its dynamic and inventive quality. The scientific method is essentially a means of discovering new phenomena, and of formulating new theories, so that the sciences constitute ever-expanding systems of knowledge, old theories being overthrown constantly by new ones, so long as that method is practised. The American authority, Sarton, has written in this connection: 'Science always was revolutionary and heterodox; it is its very essence to be so; it ceases to be so only when it is asleep.'

Stephen F. Mason
In "Main Currents of Scientific Thought"

Science and the Puritans

In origin, the American scientific tradition derived from that of England, and some similarity remained between the two traditions for a considerable time. From the start, however, an em-

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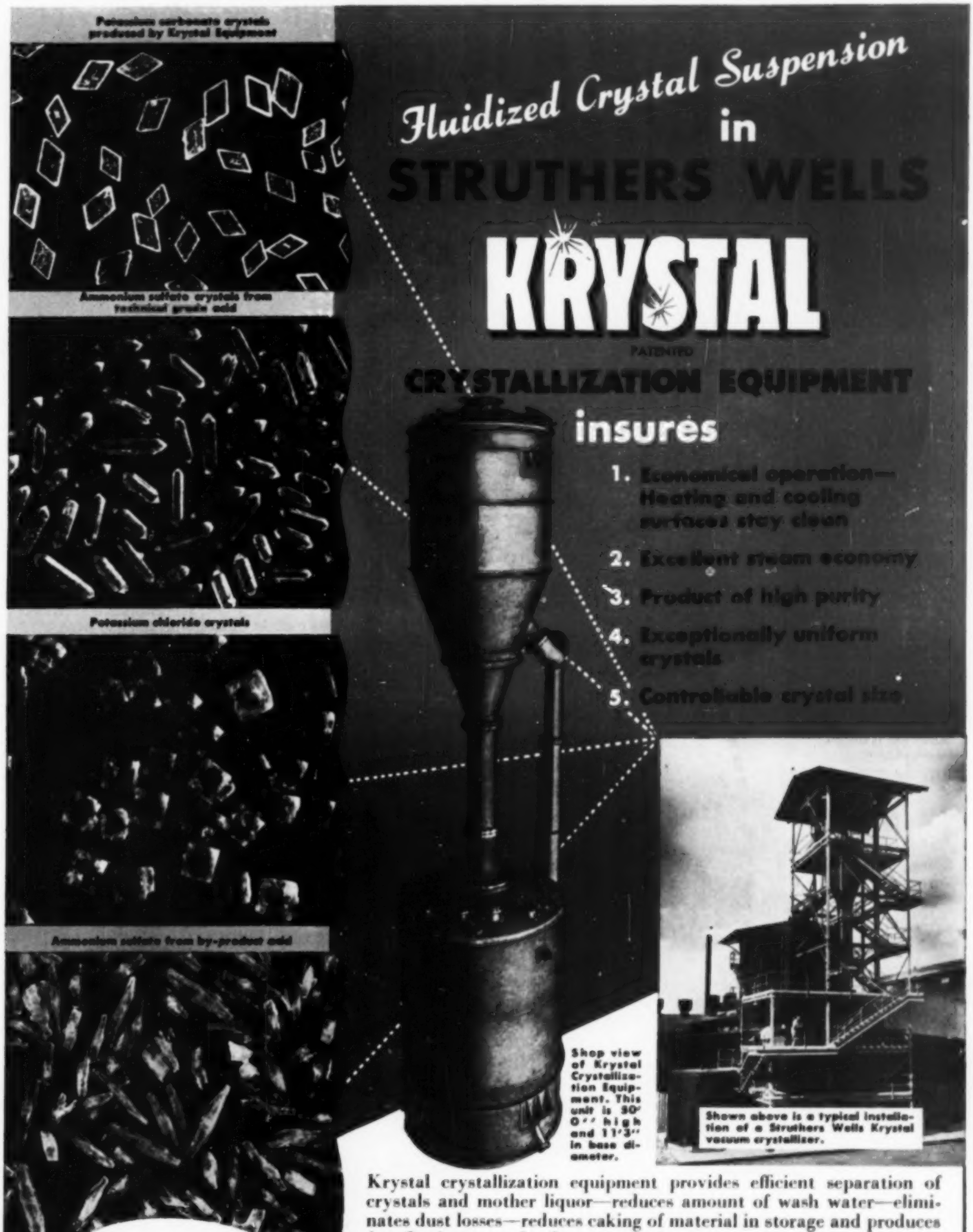

Potassium carbonate crystals produced by Krystal Equipment
Ammonium sulfate crystals from technical grade acid
Potassium chloride crystals
Ammonium sulfate from by-product acid
Fluidized Crystal Suspension
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insures
1. Economical operation—Heating and cooling surfaces stay clean
2. Excellent steam economy
3. Product of high purity
4. Exceptionally uniform crystals
5. Controllable crystal size
Shop view of Krystal Crystallization Equipment. This unit is 50' 0'' high and 11'3'' in base diameter.
Shown above is a typical installation of a Struthers Wells Krystal vacuum crystallizer.
Krystal crystallization equipment provides efficient separation of crystals and mother liquor—reduces amount of wash water—eliminates dust losses—reduces caking of material in storage and produces free flowing crystals of superior appearance.
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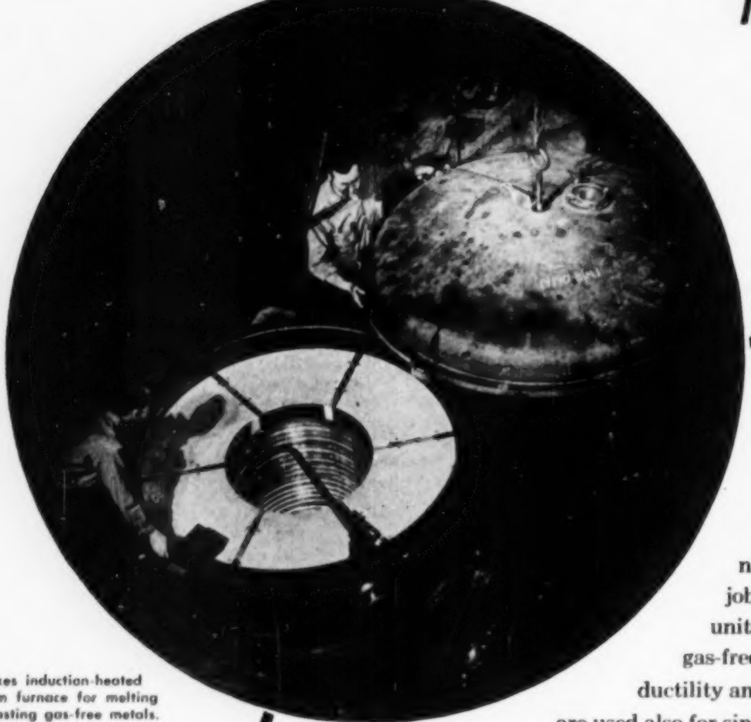
Plants at WARREN, PA. and TITUSVILLE, PA.
OFFICES IN PRINCIPAL CITIES



From one source . . . any instrumentation you need

When it comes to measurement and control, every industrial process is different. Each demands its own combination of accuracy, economy, instrument ranges, and all the numerous other characteristics that are peculiar to the individual application.

No single instrument and its accessories could possibly fit every process. So Honeywell makes a broad variety of measuring and controlling equipment that spreads across a tremendous range of applications.

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This versatile family includes *ElectroniK* indicators, recorders and controllers in circular and strip chart models, applicable to temperature, pressure, pH, power and dozens of other variables; square root flow meters for control applications; evenly graduated flow meters for cost accounting; thermometers, pressure gauges and liquid level meters; *Pyr-O-Vane* millivoltmeter controllers. Especially useful for graphic panels are the *Tel-O-Set* miniature indicators, recorders and controllers. Electric and pneumatic control systems range from the simplest to the most complex, including automatic program controls and complete systems developed for particular processes.

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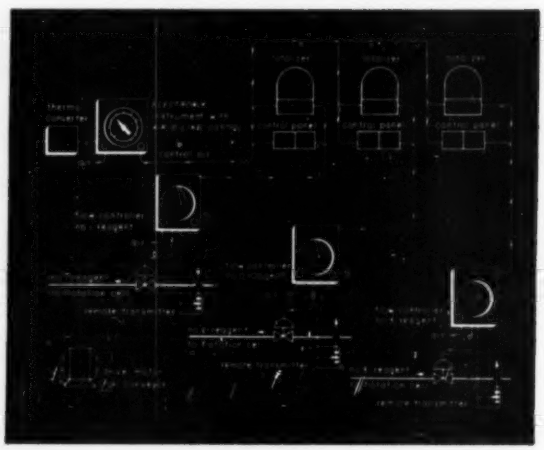
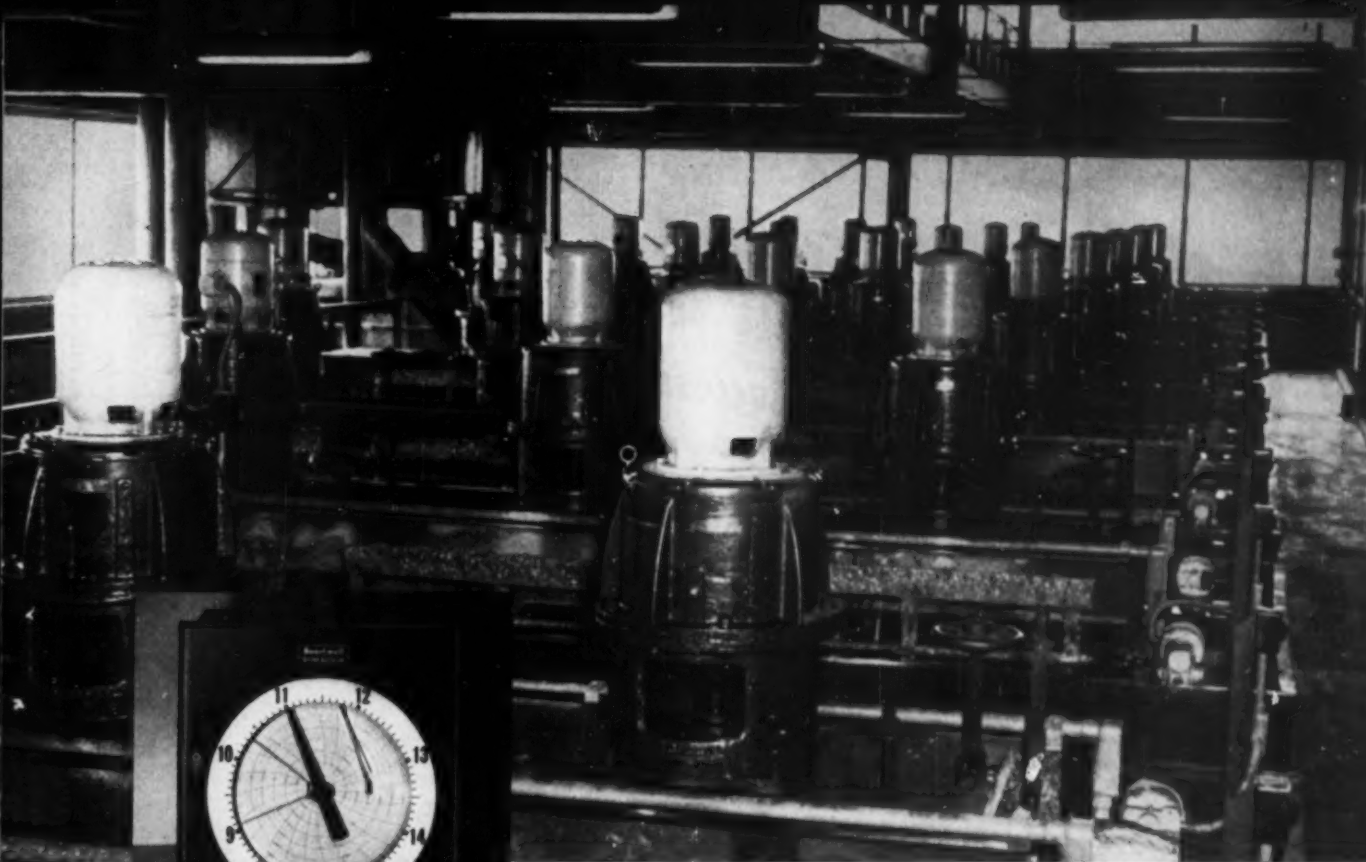
ElectroniK

pH control helps increase the yield from



Schematic diagram of pH control system for addition of caustic to phosphate flotation process.



CONTINUOUS, CONTROLLED COOLING BY SANDVIK STEEL BELT COOLERS is part of this success story*

Processing News—

COMMERCIAL SOLVENTS PATENTED SHORT-CUT TO AMMONIUM NITRATE ELIMINATES EVAPORATION AND PRILLING——STERLINGTON, LA. PLANT DELIVERS 200 TONS PER DAY

Ammonia and nitric acid react directly at 400 degrees F. to yield molten nitrate, which is cooled to solid form on Sandvik belts, broken up at take-off and then crushed.

*Reprints of CHEMICAL WEEK article describing this installation and process, available from SANDVIK on request.

This installation spotlights one of the basic advantages of Sandvik's water-bed unit ... *control of cooling rate.*

Sandvik's patented design "floats" the solid steel belt on a trough of water. The trough is sectionalized into separate tanks. Coolant in these tanks can be maintained at different temperature levels to suit the cooling rate required.

Some other processing advantages include:

- Can be engineered to cool and convey, regulate thickness and temperature while cooling; obtain desired sizes in same operation; cool solids in sheet or granular form or crystallize liquids.
- Horizontal cooling surface permits depositing material in various thicknesses.
- Belts can be fitted with stationary or movable retaining side skirts.
- Solid, cold-rolled stainless or carbon steel belts provide a smooth, hard, impervious surface.

Would a Sandvik unit improve your processing? Write, wire or phone.

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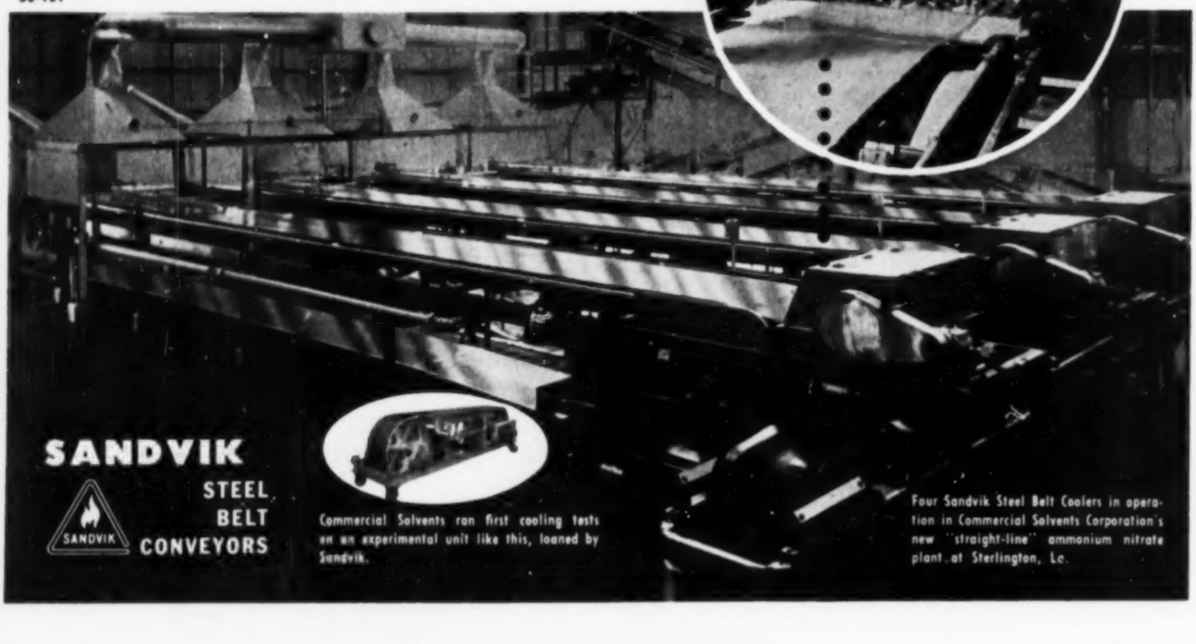
SS-101

At take-off end of Sandvik Cooler a breaker attachment breaks ammonium nitrate sheet into conveyable chips.



Commercial Solvents ran first cooling tests on an experimental unit like this, loaned by Sandvik.

Four Sandvik Steel Belt Coolers in operation in Commercial Solvents Corporation's new "straight-line" ammonium nitrate plant at Sterlington, La.

NOTED AND QUOTED

(Continued from page 24)

phasis was placed on the practical side of science in America, even more than in England. During the seventeenth century, we noted that there was something of an alliance between Puritanism and scientific activity in England, and we find that it was the Puritan states of America which contributed the greatest number of fellows to the Royal Society during the colonial period. Puritanism itself tended to give a practical orientation to science, useful applications of science being regarded as 'good works.' The first notable American scientific society illustrates in its name the utilitarian orientation of science in the New World: it was the American Philosophical Society for Promoting Useful Knowledge, which was founded by Benjamin Franklin, 1706-90, at Philadelphia in 1743.

Stephen F. Mason
In "Main Currents of Scientific Thought"

The Functional Scientist

Even as late as 1917 it was primarily the inventor, not the scientist, who was looked to by the general public as being the prime mover of technology; he was the man who changed our habits and made possible our new comforts . . . .

From the end of World War I to the beginning of World War II, the relation of science to industry in the United States was changing at great speed. The development of the atomic bomb only demonstrated to the public what was already known to many industrialists, namely that the scientists had now become inventors. The fact that so many *scientists*, and I emphasize the word, had been concerned in this development that had both brought about an extraordinary new weapon and kindled hopes for future industrial revolutions impressed . . . the entire world. The transition was complete; the scientist was no longer thought of as a man in an ivory tower, gradually unravelling the secrets of nature for his own spiritual satisfaction, but as a miracle-worker who like Watt or Edison before him could bring about tremendous transformation of man's relation to his material surroundings.

James B. Conant
In "Modern Science and Modern Man"

The Stamp of Education

We would be smug to assume that our ideas on engineering education today are so far ahead of ideas the Romans had 2000 years ago.

Frederic T. Mavis

Opinion and comment

THE NEED TO KNOW

According to the newspapers it has finally been decided that the American Public is to see films of the first thermonuclear explosion, or H-bomb.

Judging from further newspaper reports on the efficiency of the second and most recent H-bomb explosion in the Pacific, this is akin to showing film from the Spanish American War to new draftees as an example of modern warfare.

It seems to us that there are just two propositions, and only two, concerning the bomb. First it is a horror weapon, beyond imagination, and powerful enough to destroy civilization; or, second it is just another large explosion against which men can protect themselves with no more than major—but temporary—inconveniences, during and after wars, in their march to—well—whatever they are marching toward.

However, either proposition calls for more information to be given the public. If the end of civilization is in store for men, they should know it because much work needs to be done in international councils to eliminate war. If it is just another bomb, the citizens need to know just how big a bang it gives, for much work needs to be done in national councils to prepare adequate defenses. At the risk of being cynical, if the H-bomb is another firecracker, men will war and probably use it. If it is the heavy, heavy end of civilization, men might not war. But in any event it is necessary for the public to know the facts.

While science has striven, and striven mightily to give the free nations of the world a margin of supremacy, free-world diplomacy itself has been striving, just as mightily, to give mankind itself a margin of supremacy over the blind forces and suspicions, which plunge it into periodic wars.

But would not the diplomats be encouraged and strengthened by an enlightened public, instead of a pubic unable to think, and lethargic too, because it has no information to judge the safest course?

The time has come for some plain talking to the American people and to the world by the President of the United States, backed up by all the facts and figures which the Atomic Energy Commission, with wisdom, can disclose. If the public is not allowed to appraise the weapon, how can it appraise the proper course that should be taken—and in a democracy judgment is *public* responsibility. We have labored the point enough—our world has a need to know and further than that it has a right to know. The awful confusion, the conflicting reports and the resentment caused by the latest blast is a prime example of how vital, correct and prompt reporting is to the public.

The victories of the future belong to man's spirit. "Moral progress," said Whitehead, "is impossible apart from the habitual vision of greatness." Exactly so! Further progress will have to be moral before it can be physical, but progress of any sort will not come without men's "habitual vision" of things now kept secret.

WHAT IS RESPONSIBLE CHARGE?

The meaning of the words "responsible charge" in the requirements for Active membership in the A.I.Ch.E. has caused much controversy. In an attempt to help chemical engineers who must supply information on applicants for membership, and also to inform those who are applying for membership, we polled the chairman of the Admissions Committee, D. H. Spitzli; the immediate past chairman, L. C. Kemp, Jr.; and a former chairman, R. Paul Kite, on the correct interpretation of the phrase.

We found that a precise definition was impossible. A definition could not be written to cover the infinite varieties of chemical engineering. This is further proved when one remembers that chemical engineering is expanding and that those working in this field are not confined by historical definition but are free to explore ever expanding boundaries.

It is more our task therefore to describe the "atmosphere" of responsible charge, rather than precisely to define its area. One of the philological stumbling blocks is the word "charge." Responsible charge does not necessarily mean directing people but is interpreted to mean personal responsible charge, with emphasis on the "personal." As an instance, a vast amount of responsible charge would be invested in an intercompany consultant who might range through many departments and problems without having a staff to direct. Hence, though directing others may mean responsible charge, the absence of a staff does not preclude it. One of the former chairmen even suggests eliminating the word "charge" from the requirements. If the chemical engineer has been responsible for "important chemical engineering work," says he, that is all that need be said. This leads to consideration of the requirement as written in the Constitution, which states, "Responsible charge . . . means individual professional responsibility for important chemical engineering work." Again the emphasis is on the individual. A man might have a large staff of laborers working for him, but if the task is one of elementary parroting of routine procedures, this is not responsible charge or important chemical engineering work. Vital to the whole concept is the need for chemical engineering thought and decision in the work of the applicant.

As the Committee on Admissions itself put it in formulating rules and regulations about two years ago, "It is not . . . always possible to fit all applications into a strict and formal pattern and the committee must . . . depend upon the membership for information on many vital points."

It is never easy to judge qualifications from an impersonal form; it is almost impossible when the information is scanty.

Whether one is applying for membership or filling out information as a reference, he should give the Admissions Committee as much information as possible about the chemical engineering work performed.

F.J.V.A.

PRODUCTIVITY

Measurement and Control

Ewan Clague U. S. Department of Labor—Bureau of Labor Statistics, Washington, D. C.

One of the major problems encountered in writing about productivity is the loose meaning of the term itself. Productivity is not a single concept, but a whole complex of concepts which have some points in common, but also many points of difference. Expressed in the most abstract terms, productivity is a relationship between an input and an output. However, there is a variety of input factors which could be used as a base for measurement, if desired. Likewise, output can be measured in many ways, each of which may have significance for certain purposes, though they may differ quite widely in quantitative terms.

The economists, who first coined the term, applied it to all inputs. They could talk about the marginal productivity of labor, of capital, of land, or of management functions. The input factor which has generally been most significant for general economic purposes is the labor input. There are a number of reasons for this. The labor input is the largest of all the factors, since wages comprise, in the economy as a whole, about two thirds of all money payments. Furthermore, labor has a high degree of variability in brains, skills, and potentiality. Finally, labor, in the person of the worker, is not only a factor in production, but is also a final consumer.

Viewed in its broadest sense therefore, productivity is a great dynamic factor in any economic system. It measures, if satisfactory measures can be devised, the technological progress of the nation's productive organization, and it gauges fairly accurately the rise in the standard of living of the whole people.

Productivity measurement takes on many different forms. At one extreme an attempt can be made to measure the output of a single worker at his bench, relating his input of time and skill to the product which he is shaping or making. This is the area of time-and-motion study, an area which has been studied for many years by engineers and other professions. Work in this field is going on all the time, but there is no way to produce any kind of summation of results which could be used for general economic purposes.

Moving to a broader level, studies can be made of the productivity of a given plant, treating the output of that plant as a unit and summing up all the labor time which has been used in achieving the plant's production. Sometimes, for purposes of simplicity, it is possible to select certain products of the plant and then to calculate by accounting methods the man-hours required on those particular products. If these are reasonably representative of the performance throughout the plant, such a simplified input-output measurement might be used to gauge the productivity changes from one period to the next.

The scope of productivity measurement can be broadened still more with an attempt to gauge the progress of a whole industry, including a number of different plants and companies. Such industrywide summations are more a matter of general economic significance and somewhat less a matter of concern to the individual company (except insofar as the company is concerned with the comparison of its own status with the industry as a whole).

Further, productivity can be summarized for groups of industries, such as all manufacturing industries and various non-manufacturing groups yielding productivity measurements for broad segments of the economy.

Finally, of course, an attempt can be made to obtain a measurement of the productivity of the entire economy of the nation. This, as indicated above, is in a sense a measure of the technological progress of the economy and the gauge of the standard of living. Even this over-all measurement can be done in different ways.

Although productivity measurement has such a widely varying scope, ranging from a work bench to the economy as a whole, the problem of measurement in all these cases has a common foundation—namely, data on output in all its forms and data on labor input.

Productivity Measurement from a Plant or Company Viewpoint

Productivity measurements are being made all the time by cost accountants, engineers, and methods personnel. A researcher, Irving Siegel, recently stated: "Productivity still plays its most vital role under assumed names in the countless calculations and decisions in the . . . profit-motivated business community."

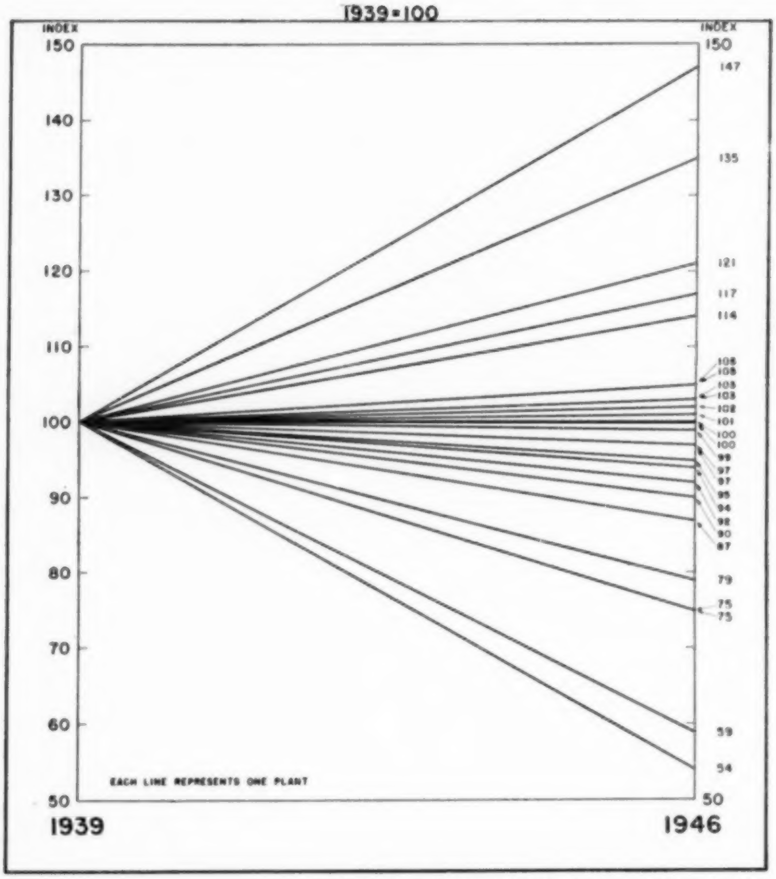
Over recent years there has been an extremely large increase in the amount of record keeping and accounting done by industrial establishments. Most of this has been to record such data as will help the company increase output and reduce the input or costs of the productive processes. These operating records of work performance are, of course, basic parts of productivity measurement. This increase in record keeping is implied in a report by the American Institute of Accountants which shows that the number of certified public accountants has more than doubled from 1940 to 1951, and, in another report by the National Association of Cost Accountants, it is stated that its membership, which is by training and experience particularly adaptable to productivity measurement, has about doubled since the beginning of World War II. The expense of constructing and maintaining detailed records of performance and costs has been enormously reduced over the past ten years by the widespread use of office machines, which increased the productivity of the accountants who measure it. In 1947 shipments of accounting and bookkeeping machines

Ewan Clague, head of the Bureau of Labor Statistics, has been in his present position about eight years. Prior to this he was director of the Bureau of Employment Security in the Social Security Board where he served about ten years. He is a career government employee, with more than twenty years of service. Prior to entering the government service, Dr. Clague did research work in unemployment and taught courses in economics and statistics at the Pennsylvania School of Social Work, affiliated with the University of Pennsylvania. He did his graduate work at the University of Wisconsin.

were three times as great as in 1939; shipments of adding machines two-and-a-half times as great over the same period.

Since virtually all labor-cost records are derived from man-hour data, there should be no major difficulties in using the basic man-hour data as another form of cost analysis. Examining hours separately and before translation into dollar terms, permits a plant to avoid changes in the dollar which has been vulnerable, even in short periods, to the workings of inflation or deflation. There has actually been a movement in the past five years among a number of plants to keep some records and make some analysis, using man-hours as a basic item. Many people are gaining a better understanding of the vital potential contained in an hour of work, and how the proper use of this potential can give a competitive advantage to the user.

A group of plants manufacturing the same product can be taken as an example. Generally speaking, the prices paid for raw materials, power, and labor will not vary much from plant to plant. Consequently, there is little chance for the individual plant to attain cost advantages via any of these basic items. When such advantages do exist because of particular location or other fortunate circumstances, usually they can be maintained only for the short run and eventually they disappear. The individual plant's biggest opportunity for competitive advantages lies in the vital potential of an hour's work. What is actually accomplished in a man-hour varies widely from plant to plant within our hypothetical industry, as it does in all industries which comprise our economy.



Courtesy: U. S. Dept. of Labor, Bureau of Labor Statistics

Fig. 1. Plant divergence of total factory man-hours/unit for the manufacture of leather.

Figure 1 shows the net changes over a 7-year period, 1939-46, of the man-hours of work required per unit of product in the manufacture of leather. Expressed in these terms, low man-hours represent high productivity. It should be noted that there were two plants whose unit man-hour index dropped to nearly 50, which means almost a doubling of productivity, two others with a man-hour requirement of 75. Yet in the same industry there was a plant with an index of nearly 150—a loss in productivity of nearly one third.

Figure 2 shows the wide variation in productivity which can exist within an industry at the same period of time. This figure shows the plants classified into four groups, from the lowest to the highest man-hours per unit. In men's work shirts (per dozen) the lowest group had an average of 3.5 man-hours, and the highest averaged 6.4 man-hours, nearly double the lowest. The range for individual plants would, of course, be even greater since some of the lowest were below 3.5 and some of the highest were above 6.4.

A still wider range is shown in gray iron foundries, where the highest group is nearly four times the lowest. In all of these industries and particularly in foundries, allowance should be made for the fact that products are not identical and perhaps some of the divergence is due to this factor.

An interesting question might be, why do low-productivity plants with large amounts of labor continue to survive in the industry? It may be that these wide divergences become possible during periods of inflation when practically all products of the economy are in heavy demand. In a more vigorous competitive situation, it is probable that the low-productivity plants with the high labor costs would be forced out of business, if they did not take steps to improve their efficiency.

Some companies with advanced accounting systems have not only recognized the value of analysis in terms of man-hours, but have actually designed departmental budgets in man-hour terms alone. A departmental foreman is shown the number of budgeted hours allowed him for the coming months for a given amount of production, and in many cases he finds this concept easier to work with than earlier budgets which were shown in dollar terms only.

In explaining why productivity measurement at the plant level is now at the threshold of acceptance by the business community, it is not sufficient to say that this has resulted alone from the increase in record keeping, accountants, and office machinery. Contributing largely to this development has been the phenomenal growth of trained management personnel. For example, there were 72,000 degrees awarded in business and commerce subjects in 1950, five times as many as in 1920. In the case of engineers, the *Washington Post* stated recently: "Fifty years ago American industry employed one engineer to every 250 production workers." This is in contrast with a recent announcement by the General Electric Co.: "Today, out of General Electric's 226,000 employees, one in 20 is an engineer." This new rising group of trained persons has brought to the industrial scene an enormous stimulus toward progressive management practices, including the measurement of productivity at the plant level.

Industrial Uses of Productivity

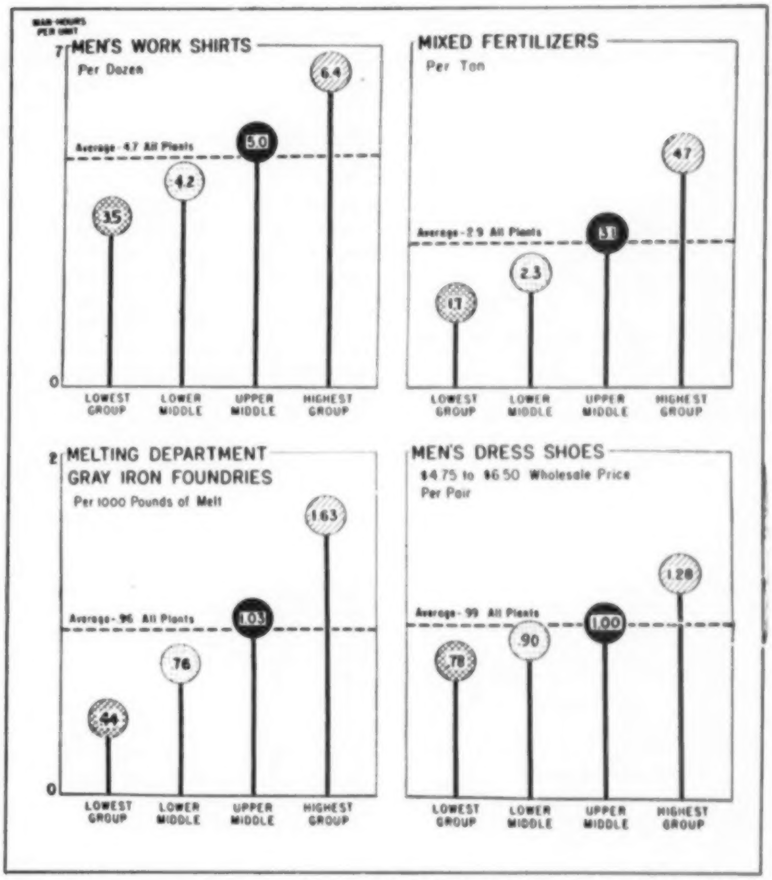
One of the uses which industry makes of the productivity concept is in the various cost-control systems in effect today. Time-and-motion study to establish standard performance rates in industry is, at the operational level, definitely a partial measure of productivity. This partial measure is generally translated into dollar terms and accumulated for the individual departments in a plant to serve as a control of operations for the departments. From this control record, plant management can observe the plus-or-minus variances of a department from a predetermined standard of performance. Also it can determine these same variances in the manufacture of a single product or a group of products. In a large sense this information is used primarily to construct costs for individual products.

Time study alone, however, does not in the full sense measure plant productivity, because it generally neglects the indirect labor functions. Figure 3 shows the extent to which indirect labor costs affected productivity in a number of industries during the war and postwar periods, 1939-1948. In a general way direct labor costs were being reduced, but indirect costs tended to rise. This is not a surprising development; in fact, it may represent the normal method of improving productivity.

There has been a growth in recent years of plans which are somewhat more comprehensive than simple time study. These are the types represented by the Scanlon Plan, the Eddy-Rucker Plan, the Lincoln Electric Plan, and others which are designed to bring the workers in the plant (and their union organizations) into the project for increasing output by saving labor time. There is no doubt about the fact that with the rapid growth of trade unionism in recent decades, labor is becoming, like industry, much more conscious of the productivity concept. Worker cooperation is absolutely essential if the maximum level of productivity is to be obtained.

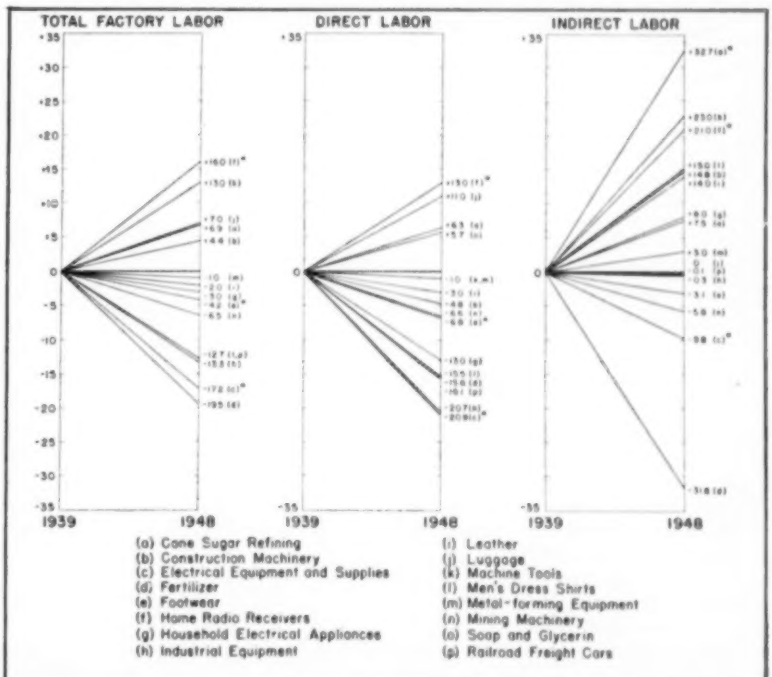
Interest by business enterprises in productivity is by no means limited to the analysis of man-hour input alone. Indications have come to the Bureau of Labor Statistics of much sound work being carried on by industrial economists in an attempt to establish practical techniques which would include materials, supplies, power, and plant charges in the productivity equation.

A few years ago the Bureau of Labor Statistics made a study to determine how productivity data were being used in American plants. Forty manufacturing firms and fifteen industry associations were interviewed and asked about their use of the Bureau data on productivity. All of the companies stated that



Courtesy: U. S. Dept. of Labor, Bureau of Labor Statistics

Fig. 2. Averages of man-hours/unit of output. Four selected industries (1949). Plants classified into four groups from lowest to highest man-hours/unit.



Courtesy: U. S. Dept. of Labor, Bureau of Labor Statistics

Fig. 3. Per cent changes in man-hours expended per unit.

the productivity data were used as a reference point for comparison with company performance. Ninety per cent of the companies used the published reports for discussion or training purposes. Sixty-five per cent of the respondents used the data in periodic re-evaluation of job ratings, work standards, and production operations. Fifteen per cent used the data to develop more accurate estimates of future and potential production capacity.

Productivity from a National Point of View

For more than a half-century there has been a general interest in productivity measurement from the point of view of the economy as a whole or of major segments of it. Back in the 1890's soon after the organization of the Bureau of Labor Statistics, the Congress authorized a major survey of productivity. The Bureau conducted surveys over a period of several years and published a 2-volume work entitled "Hand and Machine Labor," which is one of the great landmarks in the history of productivity measurement. This study showed the extent to which machine operations had come to dominate American industrial production.

Thereafter the Bureau of Labor Statistics occasionally made special studies in particular industries, such as the comprehensive study of productivity in longshoring made by Boris Stern in the middle 1920's and the historical survey of productivity in merchant blast furnaces covering the period 1911-1926. Then beginning in the middle 1920's the Bureau began preparing another type of measurement—namely, a year-to-year series of indexes of productivity for individual industries. These were later combined to make a general index for manufacturing industries as a whole, but this was as far as that type of measurement was carried at that time. The dislocations of World War II prevented continuation of the manufacturing index. Efforts in this field were renewed in the postwar period, and at present the Bureau is working on a restoration of the manufacturing index.

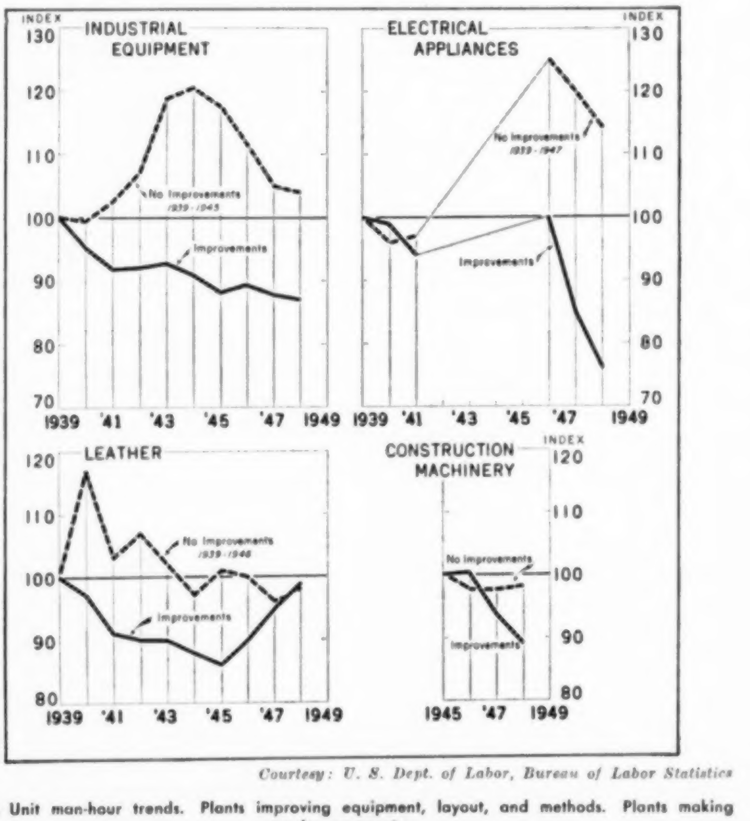
During the period 1946-1951 the Bureau also introduced the system of measurement known as "Direct Productivity Reports," for use in industries where it was extremely difficult to devise simple measures of production for the industry as a whole. Instead of trying to obtain an index of total production for the industry and relating that to the total man-hours of work, an effort was made to measure the output of one or more specific products, against which the required man-hours were measured by accounting and statistical processes. This method has the advantage of making it possible to get a more accurate measure of output from year to year, but it involves more effort in determining the approximate man-hours to be matched with the production. This type of study had a further advantage of yielding data for individual plants, so that it was possible to measure variations in productivity from one plant to another within the same industry and for substantially the same product.

The Direct Productivity Reports have another disadvantage—namely, they are much more expensive to conduct because more field work and special data collection are required. Budget stringencies have compelled a reduction in this type of work during the past few years so that at present little of it survives.

Attention is now being centered on group indexes on the basis of secondary data. One of the most difficult problems in devising these general measures of productivity is the construction of satisfactory indexes of output. These have been built up by adding together all significant items of production on a physical basis by the use of a system of weights. There is another type of approach which takes the total dollar value of the production of an industry and then attempts to cancel out the influence of price changes by means of price indexes used as deflators. Mr. Kendrick of the Department of Commerce, a year or so ago, published a productivity index for the economy as a whole based on this method of calculation. The Bureau of Labor Statistics in its present program is preparing indexes for the manufacturing sector of the economy, based on both physical volume and dollar volume of production.

From the point of view of industry, what is the meaning of the increasing technology? From 1946-1952 private purchases of producers' durable goods, machinery and equipment exclusive of plant buildings, grew almost continuously as measured in constant dollars. Many think of the prosperous year of 1929 as a high point in investment in technology. In constant dollar terms, the 1929 private purchases of producers' goods amounted to \$6.4 billion. This should be contrasted with 1946, which showed purchases of \$10 billion and the last available data (1952), which show private investment of this type amounting to \$13.6 billion, all in comparable dollars (*See* Table 1).

Clearly, the national plant and equipment were and are being subjected to a refurnishing of major proportions. Plant-level productivity measurement during such a time can identify the effects of new equipment, time lags in



Courtesy: U. S. Dept. of Labor, Bureau of Labor Statistics

Fig. 4. Unit man-hour trends. Plants improving equipment, layout, and methods. Plants making no improvements.

extracting and producing raw materials to keep pace with the new equipment, problems of training personnel, need for additional supervisors, and most important, perhaps, during this period, the need for carefully delineating the direct production workers from the growing number of indirect workers. Efforts in this field have disclosed that as equipment and machinery are taken into an industry in large numbers, the group of indirect workers, i.e., technicians and others, also increases materially.

Measurement of productivity over these postwar years, marked by expanding technology, can be interpreted in a large degree in the light of the new machines and equipment entering American plants. Studies have shown that over a period of years technology is the principal factor affecting productivity. (*See* Fig. 4.)

A dramatic example of the effects of a technological change is shown in the Bureau's recent factory performance study in the men's shoe industry. Here a group of plants using the automatic toe-lasting machine is compared with another group of plants using an older model toe-lasting machine. The plants using the older model were toe-lasting from 180 to 316 pairs per man-day while those with the automatic machine ranged from 427 to 702 pairs per man-day at this operation.

It has been found that from year to year the most important factor affecting productivity, in general, is the change in volume of production—high volume is accompanied by maximum capacity utilization with consequent gains in productivity. Of course, at the same time radical changes may occur in individual plants as a result of technological advance or product redesign. Only now is a sufficient number of observations at the plant level being brought together in order to assess the effect of all of these factors upon the productivity level of industry. Figure 5 shows in a dramatic fashion the way in which productivity in a group of plants in one industry changed from one period of time to the next. It is obvious that some one variable was quite controlling in this history. The variable in this case was volume of production.

Earlier the fact was mentioned that industry and labor have been taking an increasing interest in recent years in productivity measurement. This arises partly out of the general recognition that productivity, real wages, and the standard of living of the American people are basically derived from the growth of technical progress and the rise in productivity. Figure 6 shows the extent to which the real average hourly earnings of workers in manufacturing industries in the quarter century, 1914-1939, were correlated with the rise in output per man-hour in manufacturing. It is quite clear from the figure that the two curves may vary widely from one year to another or even at different phases of the business cycle, but the long-run trend is unmistakable. The long-run rise in real wages in the United States has been sustained by productivity increases; in the long run, real wages cannot increase faster than productivity, nor, on the other hand, can they fall too far behind.

Table 1.—Private Purchases of Durable Producers' Goods *

(In billions of constant 1939 dollars)

1929	6.4
1934	2.5
1941	7.6
1946	10.0
1947	12.0
1948	12.5
1949	11.5
1950	13.3
1951	13.4
1952	13.6

* Bureau of the Census U. S. Department of Commerce.

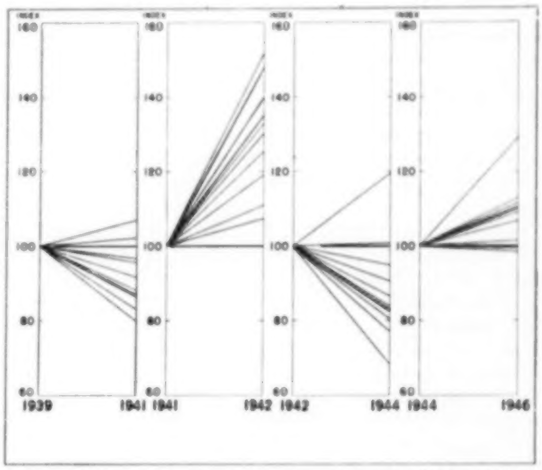


Fig. 5. Changes in man-hours/ton in individual cane sugar refineries. Selected periods.

Courtesy: U. S. Dept. of Labor, Bureau of Labor Statistics

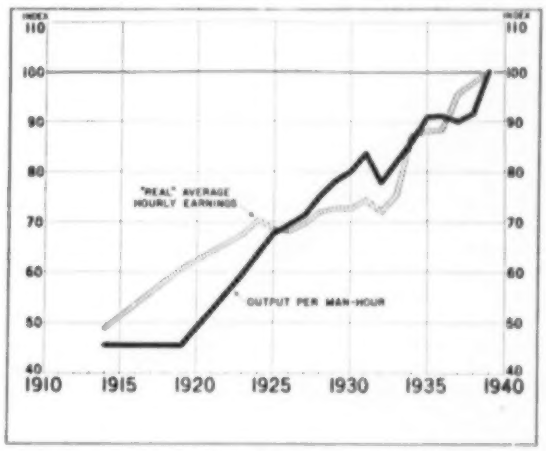


Fig. 6. Output/man-hour and "real" hourly earnings. Manufacturing 1914-1939 1939 = 100

Courtesy: U. S. Dept. of Labor, Bureau of Labor Statistics

These two curves also have another interrelationship. The pressure of rising wage rates on the employer undoubtedly contributes to the mechanization of industry and management efforts to save labor time.

Some International Comparisons

Other countries, besides the United States, have in recent years become interested in the measurement of productivity. In Great Britain, in the late 1930's, L. Rostas, an economist in the British Government, made some rough measures of the output per man-hour in British industry and the comparable output in American industry. He concluded that in many American industries the rate of output was twice and even three times that in the comparable British industry. At the same time, there were a few British industries whose productivity was approximately equal to the American.

In the postwar period European countries were concerned about first restoring their prewar levels of production and then moving forward in an industrial expansion. To achieve this under conditions of full employment was only possible through increased productivity. The United States also had a stake in European industrial recovery, and this interest was expressed through the Economic Cooperation Administration, which later became the Mutual Security Agency, and is now the Foreign Operations Administration. Along side of the active cooperation of Government, management, and labor in the United States and in European countries in achieving productivity increases in Europe, a cooperation developed in the measurement of productivity. The Bureau of Labor Statistics has had an active part in this program of measurement.

One program, which the Bureau of Labor Statistics has conducted with the support of ECA-MSA-FOA, is the Factory Performance Reports. These are case studies of manufacturing operations in individual American plants, designed primarily for use in Europe. In this program detailed information is collected which yields man-hours per unit required to make a given product, for a plant as a whole, for each department, and for each important operation. These data are supplemented by a description of each plant's equipment, layout, manpower, materials-handling methods, and other similar plant characteristics. In these case studies, as with all Bureau reports, the identity of the individual plant is zealously safeguarded.

Many American companies have been quite interested in these reports, even though they were not primarily designed for American use.. The plants covered in the reports do not necessarily represent a cross section of American industry since the ones chosen were those which would most closely correspond in size with plants existing in European countries. As a matter of fact, they are probably somewhat more efficient than the average plant in the industry studied.

European plant managers can use these reports effectively for identifying areas of low productivity and for providing guides for further action. Of course, at some point the services of trained managers or engineers must be brought in since the reports do not go into the details of how to operate a plant.

Types of studies similar to these Factory Performance Reports are beginning to come from Europe. These studies are made by European statisticians in their own countries and on a comparable basis in order to increase productivity in their respective countries. For example, the French Productivity Center has recently completed a study of output per man-hour in certain men's shoe plants in France, plants most nearly similar to the American plants shown in our Bureau study of factory performance in the United States. The lower level of French productivity is clearly portrayed by the fact that output per man-hour in the most efficient French plants was less than that in the least efficient American plants. French industry is using these studies as a guide to the methods of increasing productivity in France.

Last of all, productivity on an international basis cannot be discussed without referring to Soviet Russia.

The Bureau of Labor Statistics, on a number of occasions recently, has made some rough estimates of the working time required by the Russian workers to buy food and some other consumer goods. The results show that the Russian worker takes two, three and even more than twenty times as long to earn the money required to buy a certain article as does the average worker in the United States. There is no doubt about the fact that the Soviet production of consumer goods is very low and that the Russian standard of living is below that of even the poorer countries of Western Europe.

However, the Soviets have been pushing the output of capital goods and the expansion of industry with a view to the longer future. Professor Galenson (formerly of Harvard University, now of the University of California) has shown that Russian statistics claim an average rate of productivity growth of more than 13 per cent per year for the period 1946-1950. Later Soviet reports indicate that the rate of productivity rise has declined appreciably since that period to an annual rate of 6 per cent in 1952. Even so, the Russian figures seem spectacular, particularly considering the fact that the long-run average in the United States is only about 3 per cent per year.

Of course, three points must be borne in mind. The first is that Soviet industry was almost totally destroyed in certain sections of the country during the war, and so 1946 represented a low level of productivity from which to start. The second, and perhaps more important, point is that large-scale industrialization was still in an early stage even before the war, and that the level of productivity at this time had nowhere near reached the Western level. This point is well developed by Irving Siegel in the Journal of the American Statistical Association for March, 1953. The third fact is that Russian statistics (at least as published for the outside world) are extremely scarce and quite unreliable.

Nevertheless, the tremendous drive of the Soviet leaders has been directed to the longer future. In the short run, they have starved the Russian people in consumer goods in order to expand their factories and capital equipment. The proportion of national income in Russia which is turned back into the creation of new capital goods is higher than it is in the United States. This means that, even allowing for all the known and unknown inefficiencies of the Communist system of production, the industrial potential of Soviet Russia may be gaining on the United States.

It may be that the Russian threat will not take the form of World War III, but rather the form of a race for production—a build-up of the industrial potential of their economy. If that is the case, the United States cannot ignore the importance of increasing productivity in this country. Can we maintain the tremendous productivity lead which we now have? The answer to this question may be vital to our survival. It is for this reason that it is important for the American people to keep productivity at the forefront of their thinking, and to devise measures which will keep them informed of its progress.

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PRODUCTIVITY

in the Chemical Industry

R. F. Bruckart

Agricultural & Mechanical College of Texas, College Station, Texas

Although much has been said and written about productivity, some confusion about the meaning of the word still prevails. It is often used incorrectly; for example, people speak of increases in productivity when, actually, they mean increases in production. These two concepts are entirely different. Production refers directly to output, and productivity refers to the effectiveness of the expenditure of resources for the production of goods or for the provision of services. Frequently the measurement of productivity is expressed as a ratio, varying with the contributory aspects of production which are being studied.

Criteria for short-term measurement of performance have been developed in the form of budgets, standard costs, and similar measures. Long-term evaluations are not so readily available, however, especially in industries manufacturing a variety of products. Measurement and subsequent remedial action must be directed, of course, at the productivity of each factor in production.

Various government agencies employ a somewhat different concept of productivity. Productivity as defined by the U. S. Department of Labor is "the ratio between a given quantity of production to . . . the various input factors . . . required for such production." The Department states that better processes, better machines, and better handling of material also contribute to the steady improvement of productive efficiency. This idea is closely associated with a reference by the Wage Stabilization Board to "increased efficiency resulting from improved managerial techniques and technological advances." Thus the U. S. Department of Labor relates productivity to the expenditure of human effort, or a single element of cost; whereas management is interested in measuring all effort, or several elements of cost.

How Can Productivity be Measured?

The measurement of productivity can be expressed as a ratio of input in the form of production resources to output in the form of production obtained from the consumption of these resources.

In industries where relatively large numbers of workers are employed and where human effort contributes greatly to the production of finished products, productivity is measured rather easily in output per man-hour, per man-shift, per man-day, or per man-year. In the ratio mentioned above the numerator is an assessment of the output in physical or financial terms and the denominator is the input in labor time. In process industries, however, in which the predominance of continuous-flow equipment requires relatively smaller quantities of human effort, greater difficulty is experienced in securing an index number of productivity. The chemical industry is generally conceded to fall within this second category; and this paper will treat investigations which have been attempted, concluded, or suggested in the chemical industry.

Certain limitations attach themselves to any attempt to evaluate and measure such an intangible and frequently vague concept as *productivity*. It appears that the further the measurements are removed from shop-floor activities, the more obscure and misleading they become. Measurements of the over-all activities of a plant or of a department in a plant must be treated with caution, for they are recognizably of limited accuracy.

Inasmuch as they reflect trends, however, they are useful when considering over-all policy. For controlling day-to-day activities measurements must be confined to the departmental level. Without attempting to be cavalier in attitude toward purely statistical data, one might suggest that they be treated with care because they frequently must be supplemented by qualitative data and explanations of why things are as they are shown to be.

Relationship Between Output and Operator Hours

The relationship between the factors of operator hours and output may be expressed conveniently either as output per man-hour or as man-hours per unit of production. Wessel (*14*) has set forth a correlation between operating labor data for chemical processes and man-hours per ton required for each of the steps in the process. Combining the data originally described by Chilton (*3*) and by Faith, Keyes, and Clark (*7*), Wessel demonstrates without regard to the particular process a significant relationship between operating labor in man-hours per ton per processing step and the size of the plant in tons of product per day. This is illustrated in Figure 1.

Three distinct trend lines are provided by Wessel: the highest set of values represents those plants which have secured increases in capacity through a duplication of smaller units without developing correspondingly large reactors and adequate instrumentation; the central trend line represents combinations of batch and continuous processes; the lowest line represents units, or gases or liquids only, with a high degree of instrumentation.

An example is the contemplated operation of a 100-ton/day plant manufacturing soap glycerine. In this process seven steps are involved: precipitation, salting evaporation, salt recovery, foot distillation, sweet water evaporation, char treatment, and final filtration. From charted values it is observed that for 100-ton/day capacity, 0.5 man-hr./(ton)(step) are indicated, or a total of 3.5 man-hr./ton total. With a figure of 0.7 man-hr./(ton)(step), taken from the upper curve, a total operating labor value of 4.9 man-hr./ton is indicated. This compares favorably with Chilton's value of 4.0 man-hr./ton value. Comparative figures for existing equipment may be secured to determine whether significant deviations exist among various steps or among several manufacturing plants.

Difficulties in the use of these data could arise in the division of various processes into steps and in the size of typical plants. When employed with reasonable caution, however, they are helpful to those who require quick estimates for such values.

Others have attempted the correlation of similar relationships, occasionally with somewhat less success. An attempt by Thompson (*13*) to secure correlations of original plant investment, net sales, gross sales, and net income with the number of technical employees in engineering and scientific work was one of these. Figures secured from 100 chemical plants were analyzed to determine what relationship existed between the total number of technical employees or technically supervised employees and plant investment, and what investment per employee was found for varying conditions. The categories employed proved excessively broad, however, and statistically significant relationships among these variables were not secured. But such attempts have not been without value, for they have served to underscore the technical difficulties which attend any effort to proceed with marked success in this difficult area of investigation.

Added Value per Unit of Labor Cost

In an attempt to overcome the influences of variations in products and to take into account some of the other factors involved, the added-value measurement of output was devised. In this concept production is "value added by manufacture," that is the sales value of the output less the cost of the raw materials contained in the output. This measurement can best be used for comparing results of one period with those of another of the same firm or of different firms producing for the same market. Such ratios must be used with caution, however, for they can be affected by many outside influences and may easily lead to wrong conclusions.

Bruckart and Crum (*2*) cite figures from ten industries analyzed by this technique. A "composite figure of productivity" representing the percentage relationship between value added by manufacture and the total sales volume for each industry was established. This figure employs value added by manufacture as the numerator and total sales as the denominator. Among ten industries these ratios vary from 0.264 in the petroleum industry to 0.675 in the printing and publishing industry. The value for the chemical industry is shown as 0.503.

The determination of an individual plant productivity index is then calculated by applying this ratio to total sales volume and dividing the product by total man-hours worked for the year. The index of productivity secured is expressed as "dollar value added by manufacture for each man-hour worked."

Comparative figures for various ranges of companies have been established. In the state of Texas three industries show the index values listed in Table 1. An apparent advantage of the small company in the lumber and wood products industry is indicated in rather strong contrast with the Chemical and Allied Products industry, where the productivity advantage of a large company is evident.

Further graphic analysis of annual sales within the various industries shows systematic variation with the average size of the plant. In addition, a figure identified as "turnover index" has also been employed for comparative purposes. This is expressed as the ratio of the number of workers employed during the year to the average working force.

Such figures, which are interesting and frequently useful, are immediately subject to certain limitations in their application. Several which have been suggested (*8*) are:

a. The selling price of the product may have nothing whatever to do with the efficiency of production but may be strongly influenced by supply and demand.

Table 1.

DOLLAR VALUE ADDED BY MANUFACTURE PER MAN-HOUR WORKED (STATE OF TEXAS)

	Avg. no. of employees		
Industry	1-19	20-99	100 and over
Chemical and allied products	$4.18	$5.23	$9.97
Printing and publishing	2.49	2.18	2.66
Lumber and wood products	4.20	3.45	1.42

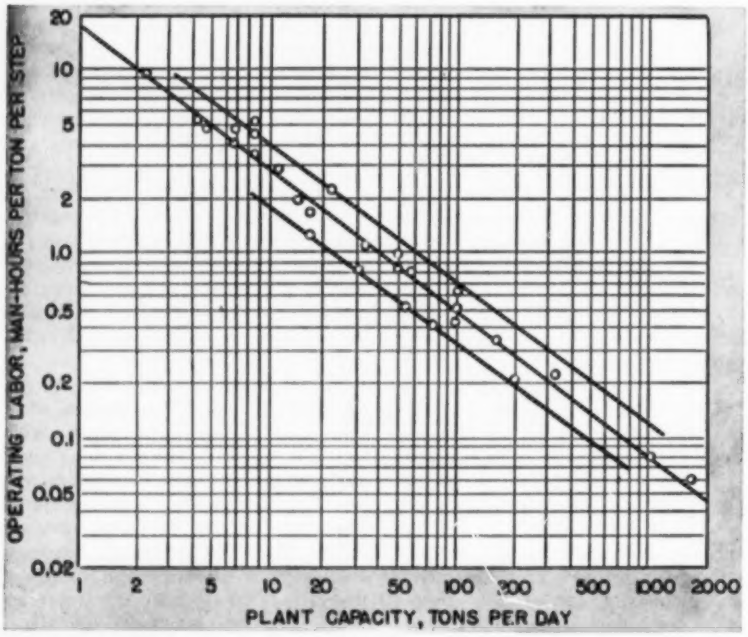

Fig. 1.

b. It is possible under some circumstances for a firm with low productivity to show a better profit than one with high productivity.

c. Even when selling prices are normally based on costs, it is a common practice for profit to be added as a percentage of the cost *including materials*. The value of the materials used is here expressedly excluded from the formula but may have an important effect on the profit margin.

It has been pointed out also that ". . . productivity series based on value are affected not only by changes in physical productivity but by shifts from products with high value (or value added) per worker to those with low value (or value added) per worker or vice versa." (*4*) Further comment suggests that "the measures . . . which make use of the dollar have advantages of being fairly acceptable to industry which typically computes many of its ratios in terms of dollars. The main disadvantage . . . arising from the use of the dollar is that which refers to the distortions . . . arising from monetary fluctuations." (*11*)

In spite of all the limitations suggested, the added-value index appears to give one of the truest measures of output in the economic sense. Since it has proved valuable to relate this measurement of output to labor costs, it apparently will also be found useful in some instances to relate it to the cost of other factors of production in the form of rent, interest, and depreciation.

Manpower Equivalent

The most recent development in the search for a measurement index of productivity has been suggested by Dr. R. Beeching and Sir Ewart Smith, a director of Imperial Chemical Industries, Ltd. (*12*) They point out that the over-all measurement of the effectiveness of a complex organization can do no more than give a general indication of whether the long-term trend is satisfactory or not; yet there is a need for a means of analyzing and guiding efforts of management to achieve improvement. The over-all measurements of productivity should be synthesized, therefore, from measurements of the departments or elementary operating units which make up the larger organization. The comprehensive measurement of effectiveness must take into account all input factors, which these writers suggest can best be done in terms of a "manpower equivalent."

Langenberg (*9*) has employed this technique in an interesting manner. He describes the manpower equivalent as a concept "representing the invisible men who stand behind the visible personnel in any manufacturing unit and embodied in capital required per worker." Thus the manpower equivalent expresses various factors of input as hours. For example, an expenditure of $8,000 for labor represents 4,000 hr. at an average rate of $2 an hour; and an expenditure of $8,000 for depreciation on machinery is assumed to be equal to 4,000 hr. paid by the payroll department. Repair and expense costs may also be converted to the same units and combined with the earlier figure for a composite factor of input. The measure of effectiveness takes the form:

volume of output ÷ (total payroll hours charged to manufacture + manpower equivalent of depreciation + manpower equivalent of repairs and maintenance).

The following example illustrates the procedure involved. The total wage and salary hours charged to all manufacturing units in a chemical plant are shown in Table 2.

The second set of figures to be secured is the manpower equivalent of depreciation of machinery and equipment, which is determined by dividing the annual charge for depreciation by the average annual hourly rate of the wage payroll. This is shown in Table 3.

The manpower equivalent of repairs and maintenance is also calculated in a similar manner, as illustrated in Table 4.

These items are summarized in Table 5.

From these figures the productivity ratios may be calculated, as shown in Table 6. Further analyses and elaborations concerning the calculation of savings, the determination of the elements

Table 2.—Wage and Salary Hours Charged to All Manufacturing

	Hr.
1948	40,000
1949	39,125
1950	38,750
1951	36,590

Table 3.

CONVERSION OF DEPRECIATION OF MACHINERY AND EQUIPMENT INTO EQUIVALENT HOURS BASED UPON AVERAGE PAYROLL RATES

Year	Total Depreciation of Equipment in Use	Average Hourly Rate	Equivalent Hours
1948	$42,000	$1.30	32,000
1949	48,500	1.40	36,640
1950	55,000	1.50	40,870
1951	62,000	1.60	45,350

Table 4.

CONVERSION OF REPAIRS AND MAINTENANCE OF EQUIPMENT INTO EQUIVALENT HOURS BASED UPON AVERAGE WAGE PAYROLL RATE

Year	Actual Repairs and Maintenance Expense	Average Hourly Rate	Equivalent Hrs.
1948	$17,500	$1.30	13,500
1949	19,400	1.40	13,850
1950	21,000	1.50	14,000
1951	21,000	1.60	13,450

Table 5.

COMPOSITE INDEX OF INPUT REFLECTING WAGE AND SALARY PAYROLL HOURS, EQUIVALENT HOURS OF DEPRECIATION AND REPAIRS AND MAINTENANCE

Year	Manufacturing Wage and Salary Hrs.	Equiv. Depreciation Hrs.	Equiv. Repairs and Maintenance Hrs.	Composite Index
1948	40,000	32,000	13,500	85,500
1949	39,125	36,640	13,850	89,615
1950	38,750	40,870	14,000	93,620
1951	36,590	45,350	13,450	95,390

Table 6.

RATIOS REFLECTING PRODUCTION PER INDEX HOUR

	1948	1949	1950	1951
Production volume	$444,000	$468,000	$501,000	$496,000
Index hours	85,500	89,615	93,620	95,390
Percentage ratio	100%	104.8%	109.5%	111.5%
Production value per index hour	$5.19	$5.22	$5.35	$5.20
Percentage ratio	100%	100.6%	103.1%	100.2%

which have caused increases or decreases in productivity, and trends of dollar expenditures are possible in this technique; however, these go beyond the scope of this paper.

Langenberg points out several possible objections to this procedure.

1. A total of payroll hours fails to recognize shifts of skill and related rates of pay . . .
2. Manpower equivalent of depreciation is only as accurate as the estimated life of the asset . . . . (9)

This procedure appears to have excellent potentialities, however, and may prove to be an effective new technique for determining productivity trends and relationships.

The Improvement of Productivity

The word *productivity* has been defined as a ratio of the volume of output achieved in a given period of time to the sum of the resources which have been utilized in the achievement of that output. Consequently, as Dale (*5*) suggests, "we speak of an 'increase in productivity' when there is (a) an increase of output per unit of input, *i.e.*, resources used in production, or (b) when the same output is produced with a smaller input."

For the chemical industry these may appear as a variety of opportunities. As suggested by Smith and Beeching (*12*), they may be long-term projects requiring major capital expenditures. This includes the improvement of basic processes, of the plant, and of equipment. Intermediate-term actions include the standardization of products and the reduction of variety, which also may require capital investment. Short-term actions which are possible include the improvement in methods of plant operaitons, improved planning of work-control procedures, and increases in the effective rate of work of the employees. No great expenditure of capital is generally required to affect such benefits.

It would be possible to speculate as to what factors should be regarded as most important in achieving high productivity in the chemical industry. Frequently the factors considered of most importance are increased capital investments and improved managerial know-how. Undoubtedly these play a great part in achieving this end.

One source of reliable information has been provided recently through the report of the British Productivity Team which toured the heavy chemical industry in this country as part of the Anglo-American Council of Productivity activity. The team (*1*) describe the factors in American chemical practice which were found to be superior to their own and a few in which they thought that British practices were equal to or superior to those of the United States.

One of the areas in which American practice reportedly was superior was in the number of technical graduates who are available to industry, actually stated to be three times the number available in Britain. Another difference noted was the use of time and motion study, "particularly for the improvement of processes, maintenance, packing and materials handling, for labor and cost control, and for the proper planning and managing of jobs, coupled, where appropriate, with financial incentive plans." It is interesting to note that in only one American chemical plant of the fifteen visited did the team find an incentive plan based on work measurement, whereas it was reported to be a commonly used plan in British chemical plants, in recent years extending into plant maintenance and chemical process work. Equipment for handling materials was reported to be more abundant here but no better than that in Britain.

The use of preventive maintenance was reported to be an outstanding advantage of American plants and reportedly approached 100% in some plants visited. The "incentive of promotion" was also cited as an outstanding American superiority, as a means of stimulating payroll and staff to higher productivity. Another item mentioned is the importance of having employees informed by their union heads of the desirability of reducing costs through laborsaving devices and through time and motion study.

Certainly, as it is difficult to diagnose the cause of ineffective utilization of facilities, so it is equally difficult to prescribe a general policy which will solve the ills of all equally effectively. The ratios or indices of productivity will in themselves do little to improve industrial efficiency. A good system of measurement will help to set goals, will pinpoint inefficiencies, and will point out areas where action is required. Productivity measurement is not a substitute for action but merely a device indicating where action is required. The responsibility for action rests with management and no one else. Productivity measurement provides a basis for the action which is to be taken.

Several companies in the chemical field have done excellent work in establishing control procedures for appraising performance in financial terms. A recent report by the Du Pont Co. (*6*) and another by the Monsanto Chemical Co. (*10*) have explained the controls established by those organizations.

The measurement of productivity is a new field without a great deal of literature. The application of analytical methods for the improvement of productivity will serve to advance an already high productivity in the chemical industry to even greater heights.

Summary

Every company should have an effective procedure for measuring its productivity on an over-all basis. There are a variety of methods for doing this, all having certain advantages and certain weaknesses. Which method is used is not of major importance if one recognizes the qualities of the method used. Steps for the improvement of productivity are a natural consequence of the application of a measurement of productivity, and various means for improving productivity are available. Generally the use of capital for the provision of the latest technological equipment is cited as one of the most important of these in the chemical field. The provision of effective working methods and standardization of procedures are also important where larger numbers of workers are employed. The American chemical industry secures high productivity through effective technological developments. Further advances may be expected when effective means of measuring unit productivity are fully developed.

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AMMONIA SYNTHESIS GAS

Evaluation of Processes Using Natural Gas

B. J. Mayland, E. A. Comley, and J. C. Reynolds The Girdler Company, Louisville, Kentucky

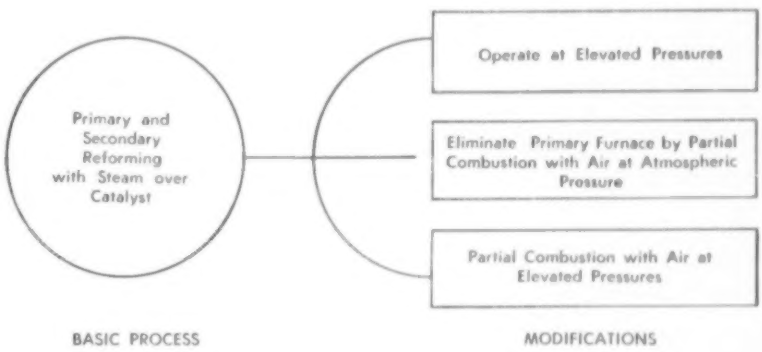
Method

In the manufacture of ammonia synthesis gas from natural gas some form of primary and secondary reforming with steam over a catalyst may be considered as the conventional process (*9*). This paper will discuss three of the various proposed improvements—the operation of the conventional process at elevated pressures, elimination of the primary furnace by partial combustion with air at low pressure, and partial combustion with air at elevated pressures. The problem then is to evaluate these changes relative to the conventional process on the basis of the costs.

As a starting point, the production of 120 tons/day of anhydrous ammonia was chosen since this is a size frequently encountered. The utilities and equipment for the synthesis loop were then taken as essentially constant among the various cases. Since the purity of the synthesis gas varies with the scheme of preparation and purification, the quantity of gas fed to the synthesis loop varies. The 350-atm. ammonia synthesis process (*4*) was considered more suitable for this evaluation than the 1000-atm. process (*8*) because the synthesis gas purities are rather high and some of the advantages of the 1000-atm. process are lost when high purity synthesis gas is used.

Four cases were set up for evaluation, a base case with conventional primary and secondary reforming and three with the proposed improvements: Case I, the conventional process; Case II, primary and secondary reforming at an elevated pressure; Case III, air partial oxidation at a low pressure; and Case IV, air partial oxidation at an elevated pressure. The essential differences are shown in Table I.

Process designs were prepared for these four cases in order to obtain equipment lists for cost estimating purposes and utility requirements. The flow diagrams are shown in Figures 1 and 2 for Cases I and IV; the flow diagram for Case II is similar to that for Case I and Case III is similar to Case IV.



Primary Reforming

Primary reforming has been used in many installations in the United States for the preparation of synthesis gas from natural gas (*9, 2*). In the primary furnace, part of the natural gas is reacted with steam over a catalyst to form hydrogen and carbon monoxide with some carbon dioxide by-product. This reaction is endothermic and so considerable heat transfer area is required. Since the temperature levels are above 1,400° F., alloy is required and the equipment is expensive. In the conventional process the pressure level in the primary is usually limited to 20-30 lb./sq.in. gauge but may go as high as 45 lb./sq.in. gauge.

Reforming data were obtained at 150 lb./sq.in. gauge as part of a pilot plant program. Because of the high temperature levels and the low allowable fiber stress, small diameter tubes with relatively thick walls are necessary. Allowable space velocities in primary reforming correlate closely with the heat transfer area. The data indicate that little advantage with respect to heat transfer coefficients or reaction rates is obtained by pressure operation. However, pressure operation does allow the use of higher space velocities in the smaller diameter tubes without excessive pressure drop while the same bed depth is maintained.

Secondary Reforming

In this step as practiced, additional natural gas is burned with air, which supplies the nitrogen (*9*). These com-

bustion products along with the effluent from the primary furnace pass through a large catalyst bed. Since the net reaction is exothermic no heat exchange is necessary and the process can be carried out in an adiabatic reactor. By a heat balance, the natural gas split between the primary and secondary furnaces and the temperature boost through the secondary furnace are readily ascertained. A typical figure is 75% of the natural gas to the primary and 25% to the secondary furnace. A 100° to 200° F. temperature rise in the secondary furnace results. Since heat transfer surface is unnecessary, the unit can be readily designed for operation under moderate pressure.

Air Partial Oxidation

This step used in Cases III and IV has received some attention from various investigators in the past but, as far as the writers know, has not been commercially developed (*1*). Thermodynamic considerations (*5*) indicate that the process is somewhat more complicated than the oxygen-natural gas partial combustion process. Because of the nitrogen dilution, temperature levels attained are not high enough for thermal equilibration without excessive preheat, and therefore, a catalyst is required. Air and natural gas are burned with approximately 50 to 60% aeration for complete combustion. Additional natural gas along with diluent steam is combined with the initial combustion products and the mixture passed over a reforming catalyst. In the design of the reactor in Case III, in which the process is operated at atmospheric pressure, conditions can be set up to resemble closely those encountered in commercially operated secondary reformers. Case IV involves the additional factors introduced by pressure operation.

Carbon Monoxide Conversion

In this step carbon monoxide is reacted with steam to give hydrogen and carbon dioxide (*9*). The mildly exothermic reaction operates at temperature levels of about 700° to 850° F. with an iron oxide type of catalyst. There has been considerable commercial experience with this process at near atmospheric pressure. At least one plant in the United States operates at elevated pressures. Pressure operation allows a higher space velocity for a given conversion and temperature level, or with the same space velocity a lower temperature level can be used.

Carbon Dioxide Removal

Carbon dioxide removal is accomplished in each case by a Girbotol regenerative absorption system employing aqueous monoethanolamine solutions (*6*). Under pressure operation it is possible to recover heat in the amine stripper reboiler by condensation of steam from the process stream and to get a somewhat better fuel economy than from other methods of heat recovery.

Low Temperature Nitrogen Separation

In Cases III and IV the gas resulting from the air-steam-natural-gas reactions contains an excess of nitrogen. This gas is ideal for mixing with a pure hydrogen stream to give a 3/1 ammonia synthesis gas (*3*). However, if a hydrogen stream is lacking, the excess nitrogen can be removed by low temperature condensation (*7*). In this step the hydrogen-nitrogen mixture at 266 lb./sq.in. gauge and 100° F. is freed of carbon dioxide by caustic wash, dried, and then subjected to heat exchange resulting in partial condensation. Refrigeration is

Table 1

SUMMARY OF FLOW SCHEMES EMPLOYED TO PREPARE AND PURIFY AMMONIA SYNTHESIS GAS

	Primary and secondary reforming		Air partial oxidation	
	Conventional	Elevated pressure	Low pressure	Elevated pressure
	I	II	III	IV
Inlet pressure, lb./sq.in. gauge	45	150	45	350
Preparation step	Primary and secondary reforming	Primary and secondary reforming	Air partial oxidation	Air partial oxidation
Purification step (a)	CO Conversion	CO Conversion	CO Conversion	CO Conversion
Purification step (b)	CO_2 Absorption	CO_2 Absorption	CO_2 Absorption	CO_2 Absorption
Purification step (c)	CO Conversion	CO Conversion	Compression to 266 lb./sq.in. gauge	Condensation
Purification step (d)	CO_2 Absorption	CO_2 Absorption	Condensation	Methanation
Purification step (e)	Methanation	Methanation	Methanation	
Compressor suction, lb./sq.in. gauge	9	105	234	234
% Inerts in synthesis gas	1.30	1.30	0.34	0.34
SCF of synthesis gas /ton NH_3	99,750	99,750	91,600	91,600
% Conversion of useful gas	90.4	90.4	97.5	97.5

Table 2

INVESTMENT

120 tons/day Anhydrous Ammonia Production

	I	II	III	IV
Preparation and purification	$2,015,200	$2,215,000	$1,922,600	$1,527,170
Compressor section	562,430	562,430	515,450	515,450
Ammonia synthesis section	1,158,780	1,158,780	1,158,780	1,158,780
Cooling towers	87,930	86,720	87,930	61,170
Compressor building	241,290	187,940	289,310	241,290
Total	$4,065,630	$4,210,870	$3,974,070	$3,503,860

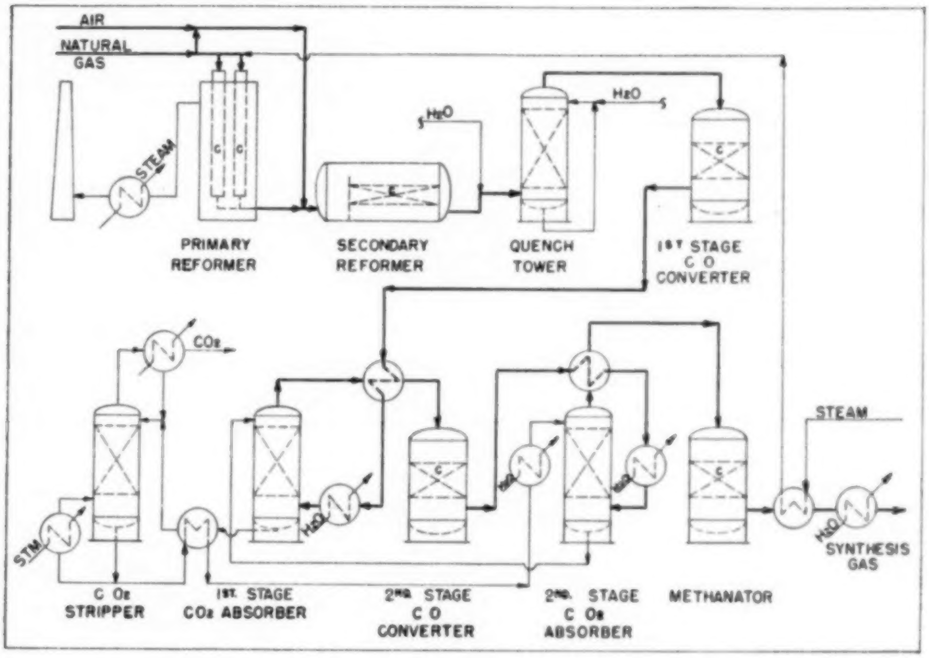


Fig. 1. Ammonia synthesis gas preparation and purification—Case. 1:

obtained by flashing the liquefied excess nitrogen at an intermediate pressure and then lowering the pressure to atmospheric through an expander and heat exchangers. Impurities, such as methane and argon, are removed with the excess nitrogen. Only part of the carbon monoxide is removed and so the resulting gas must be methanated. Some loss of hydrogen by solubility in the liquid nitrogen occurs.

Methanation

As a final cleanup of the gas, methanation is used (*10*). Traces of carbon monoxide and carbon dioxide as well as oxygen are reacted over a catalyst to methane and water. Since these reactions all consume hydrogen and dilute the synthesis gas with inerts, it is obviously desirable to limit the amount of material that must be methanated. This reaction has been carried out at atmospheric or elevated pressures with no difficulties.

Economic Evaluation

From the process designs of the gas preparation and purification units, equipment lists of the major items are prepared and cost estimated. The estimates do not need to be of a high degree

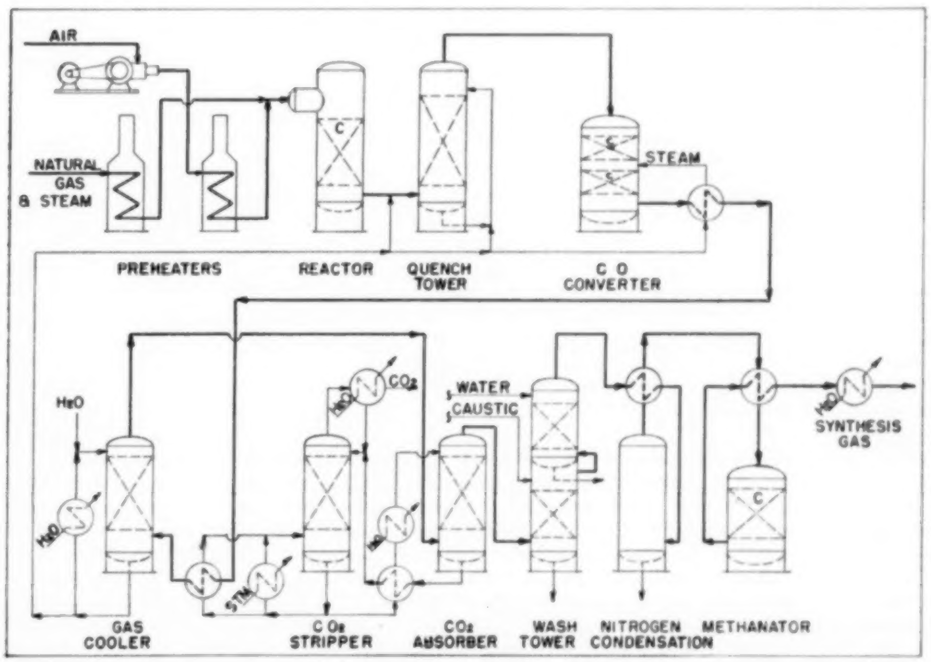


Fig. 2. Ammonia synthesis gas preparation and purification—Case 4.

of accuracy since only comparisons are desired. Care must be taken, however, to insure that costs of major items of equipment are determined on a comparable basis. Piping and structural steel are taken as 25% and 3% respectively of the major equipment. Other construction items, such as electrical, insulation, painting, etc., as well as freight, are set at the same value in all cases. A 5% contingency is then added with allowance for items which already contain the manufacturer's contingency. The cost of erection is taken as 35% of the total with allowance for items which already include the erection cost. Estimates of the other sections of the plant are based upon previous studies and are evaluated on a dollar per unit of capacity basis. Other costs such as fees, engineering, purchasing, and field charges are included as plant investment items.

The investment figures are given in Table 2. The totals for each of the four cases are complete for a battery limits plant except for storage facilities. Land cost, site preparation, and installations outside the battery limits, such as administrative and employee welfare installations, are not included in these estimates. Each item in the tabulated investment is comparable among the cases. For example, in each case the preparation and purification section delivers the required amount of synthesis gas at the same pressure and temperature. The pressure chosen was 234 lb./sq.in. gauge and in Cases I and II some of the compression investment was added to the preparation and purification section.

The utility requirements, given in Table 3, are obtained from the process calculations. Steam is expressed as a separate item. However, it is customary to express it as equivalent fuel gas requirement and this is done in arriving at the final cost figures.

The manufacturing cost per ton of ammonia is used for the final comparison of the processes. The plant investment affects directly the cost of producing ammonia. Fixed costs and maintenance are expressed as a percentage of the total plant investment. Other costs included are those for natural gas, cooling water, electric power, steam as equivalent natural gas, catalyst, chemicals, operating labor and overhead, supervision and control, and operating supplies. The cost per ton of ammonia depends upon the plant location. The cost schedule shown in Table 4 is based upon a south-central location. By the use of these values and the process requirements from Table 3, the cost per ton of ammonia is obtained, Table 5.

Discussion of Results

Operation of the conventional primary and secondary reformer at elevated pressures, as shown by Cases I and II, results in improvement but not large for the particular price structure chosen. Because of the greater number of smaller tubes with thicker walls, the investment in the primary furnace is increased appreciably. A saving in compressor investment offsets only part of this. The resulting higher fixed costs are more than offset, however, by a saving in compression cost. More fuel is used in pressure operation because of the higher temperature level required to reduce the residual methane. Most of this extra heat, but not all, is recovered and is reflected as lower steam cost.

Air partial oxidation at essentially atmospheric pressure, Case III, shows only a slight improvement over conventional reforming investment. There is considerable saving in natural gas but a compensatory increase in the power requirement. The higher power requirement is due to compression of the excess nitrogen to 250 lb./sq.in. gauge for removal by the low temperature separation. The result is a somewhat higher cost for the production of ammonia.

Table 3

SUMMARY OF UTILITIES

120 tons/day Anhydrous Ammonia Production
Quantities/Ton

	I	II	III	IV
Natural gas MSCF				
Process	22.3	22.3	24.8	26.6
Fuel	11.2	13.5	3.0	3.6
Purge credit	−2.0	−2.0	−0.5	−0.5
Total	31.5	33.8	27.3	29.7
Steam, m lb.	9.6	8.3	10.4	3.5
Cooling water, m gal.	79.4	77.0	79.4	55.4
Electric power, kwh	858	676	1,052	887

Table 4

COST SCHEDULE

Natural gas	\$0.22/MSCF
H_2O (Cooling tower)	\$0.015/1,000 gal.
Electric power	\$.006 kw.hr.
Steam	1.4 MSCF of natural gas/ 1,000 lb.
Catalysts and chemicals	
Reforming 5-10 yr. life	\$1.15/lb.
Conversion 5 yr. life	\$0.65/lb.
Methanation 3 yr. life	\$2.18/lb.
Synthesis 5 yr. life	\$0.58/lb.
Amine	\$2.57/gal.
Caustic	\$ .03/lb.
Operating labor and overhead	\$2.00 + \$.25/hr.
Supervision and control	50% of operating labor
Plant maintenance	3% of total investment/yr.
Operating supplies	\$0.65/ton of ammonia
Fixed costs	12.5% of investment/yr.

Table 5

OPERATING COST

120 T/D Anhydrous Ammonia Production
\$/Ton

	I	II	III	IV
Natural gas at 22¢/MSCF				
(a) Process	4.91	\$ 4.91	\$ 5.46	\$ 5.85
(b) Process fuel (including purge credit)	2.02	2.53	0.55	0.68
(c) Steam generation	2.95	2.55	3.63	1.08
Cooling water at 1.5¢/1,000 gal.	1.19	1.15	1.19	0.83
Electric power at 0.6¢/kw.hr.	5.16	4.06	6.31	5.32
Catalyst	1.60	1.57	0.94	0.94
Chemicals	0.24	0.24	0.82	0.82
Operating labor and overhead at \$2.25/hr. (6 operators/shift)	2.70	2.70	2.70	2.70
Supervision and control at 50% of operating labor	1.35	1.35	1.35	1.35
Plant maintenance at 3% of investment/yr.	2.90	3.00	2.84	2.50
Operating supplies	0.65	0.65	0.65	0.65
Fixed costs at 12.5% of investment/yr.	12.10	12.54	11.83	10.43
Total	\$37.77	\$37.25	\$38.27	\$33.15

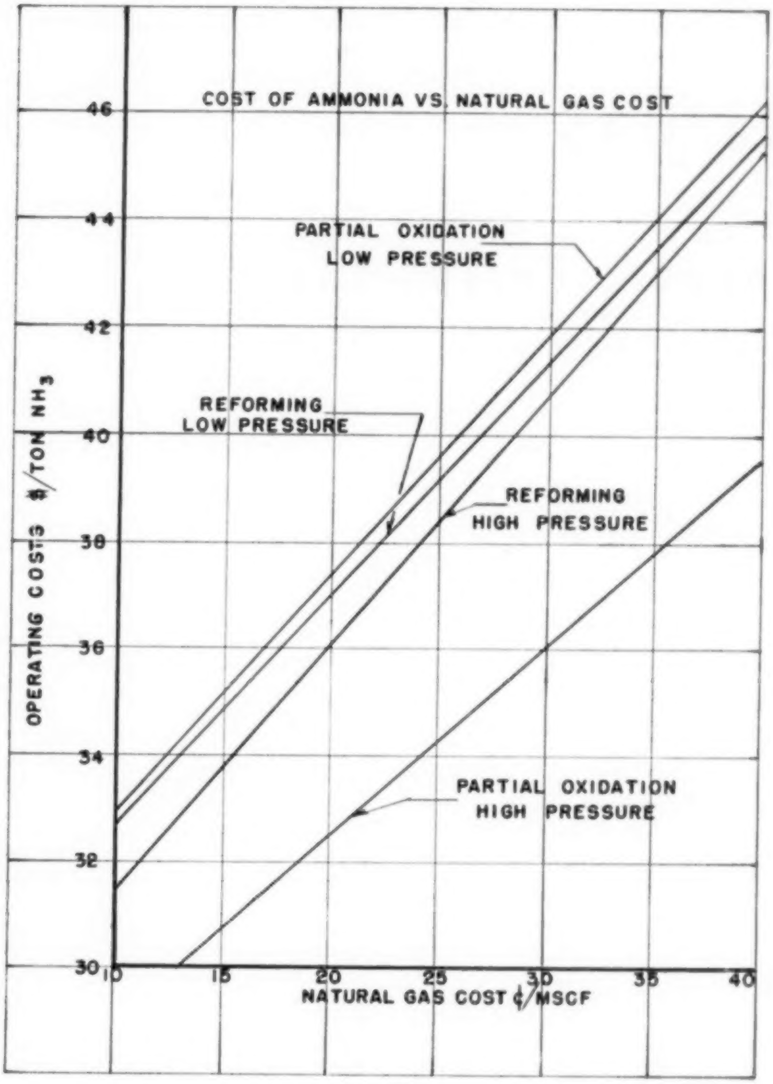


Fig. 3. Comparative cost of ammonia processes vs. cost of natural gas.

Air partial oxidation at elevated pressure has an advantage over the conventional process. As shown in the tabulation for Case IV, a substantial saving in the total production cost is made. Further, the required investment is down about 12%. The saving in natural gas is realized exclusive of steam generation. By the condensation of process steam from the carbon monoxide shift in the Girbotol stripper, a considerable saving in steam generation is effected. The saving in compression for the reformed gas by operation at an elevated pressure is more than offset by the required compression power for the air resulting in a net increase. Other savings in cooling water, catalyst, and plant maintenance contribute a small amount of the total.

The results obtained in an analysis such as this are dependent to some extent on the price structure used. It is interesting to show the effect of higher natural gas prices on the cost of production. In Figure 3 is plotted total cost of production per ton of anhydrous ammonia vs. cost of natural gas. The advantage for Case IV is considerably greater at the higher natural gas price, whereas pressure operation of a conventional reformer becomes increasingly attractive at the lower natural gas costs.

An economic comparison as presented in this paper is useful in establishing relative merits of various process schemes. However, care should be exercised in drawing conclusions from this type of study. According to the foregoing analysis, air partial oxidation under pressure has been shown to be economically advantageous, whereas atmospheric pressure operation is not particularly interesting. However, either atmospheric or pressure operation has other potential advantages which have not been credited. These are adaptability of the process to other fuels such as liquid hydrocarbons and use of the process in conjunction with an already existing hydrogen stream. In any particular study these factors may be very important and influence the choice of process. Disadvantages not considered in this study, are, of course, the unforeseen difficulties which might be encountered in engineering and contructing the plant for carrying out this process. With the conventional process, plant experience has shown what to expect in the way of maintenance, catalyst life, and fuel economy.

Pilot plant tests on the air partial oxidation step have been undertaken. The data so far obtained, as well as commercial plant data at moderate pressures, have demonstrated the operating feasibility of the process under the conditions used.

Acknowledgment

The authors wish to acknowledge H. L. Thompson's suggestion that an economic study be made to evaluate the process shown in Case IV in comparison with conventional primary and secondary reforming. Credit is also due to Robert M. Reed and others whose suggestions were used in preparing the paper. Permission of The Girdler Company to publish this paper is appreciated.

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SYNTHESIS GAS

from the Koppers-Totzek Gasifier

Friedrich Totzek

Heinrich Koppers, G.m.b.H., Essen, Germany

The recent evolution of industrial chemistry has been particularly influenced by syntheses such as those of ammonia, methanol, and of hydrocarbons by the Bergius and Fischer-Tropsch processes.

Raw materials for these processes include carbon monoxide and hydrogen which have been produced from coke, coke-oven gas, or natural gas. Their conversion into synthesis gas is effected by well-known apparatus and processes; for example, water-gas generators, rotary-grate producers, and thermal- and contact-cracking plants. In many countries these fuels are either not available or are in dwindling supply, so that today such lands have been excluded from the advantages of modern chemistry. Many areas do have available, however, other fuels such as poorly or noncoking coals, lignite, brown coal, and peat. Thus, it is readily understood that demands for a new process whereby coal—and indeed any type of liquid or solid fuel—can be gasified, have become increasingly insistent.

The lack of petroleum in many countries like Germany was the incentive behind the development of the production of liquid fuel from bituminous and brown coals which resulted in the Bergius and the Fischer-Tropsch processes. The need for such developments was based on the ever growing use of energy machines using liquid fuels, which became necessities of civilization. This was followed closely by the application of energies to machinery used in war such as tanks, airplanes, battleships, and submarines. These new uses in war in turn endangered supplies of the precious liquid petroleum when transported from foreign countries overseas. In the late 1930's a dilemma developed—there was apparently a great plenty of petroleum, but it was either available with difficulty of transportation in war times or economic obstacles prevented its ready use in countries with no indigenous natural petroleum because enough could not be offered to barter for the oil. Thus, the great interest in processes came about to produce synthetic oil first in Germany and then in America during the 1940's. The United States became even more keenly aware of the danger of dependence on foreign oils when it learned of the Snorkel-equipped submarine and the fact that this knowledge fell also into unfriendly hands. This stimulated the American synthetic-oil program as demonstrated at the Louisiana, Mo., plant of the U. S. Bureau of Mines, which incorporated both the older German "know-how" as to synthetic-fuel manufacture, the American improvements, and last the combined "know-how" and skills of two concerns—namely, Heinrich Koppers G.m.b.H. of Essen, Germany, and Koppers Co., Inc. of Pittsburgh, Pa., in the field of total gasification.

Before the construction of the Louisiana, Mo., total gasification plant it had not been possible to convert lignites, noncoking coals, brown coal, and peat economically into synthesis gas. Serious work was begun in the middle thirties to develop a method that would allow such fuels to be converted into a superior synthesis gas. It was soon realized that for such basically different types of fuels an initial physical form would have to be chosen into which they could all be converted in common—that was dust.

The firm Heinrich Koppers began in 1938 its investigations in the gasification of coal dust. This work resulted finally in a successful solution of the problem.

A concurrent-gasification process was the result of this basic study. Naturally, for reasons of heat economy, a countercurrent gasification process, for example, the Kerpely-Producer, is preferable. However, inasmuch as the problem was concerned with the production of the highest quality synthesis gas from the cheapest available fuel, many advantages, from a chemical point of view, reside in a concurrent-gasification process; for example, no heavy hydrocarbons, no condensable constituents, and no gum formers are produced.

In this process for the first time coal dust in admixture with pure oxygen was introduced into a gasifier. The steam employed in the gasification reaction envelops the resultant primary reaction zone of the gasification reaction as a sort of mantle. The endothermic reactions taking place in the gasification process lower the temperature sufficiently so that the gasifier shell can be lined with normal refractories and the ash remains unfused to the extent of 80 to 95 per cent depending on the ash-fusion temperature. This ash is carried out of the gasification chamber in suspension with the produced gas.

The essence of the process comprises the introduction of a homogeneous mix-

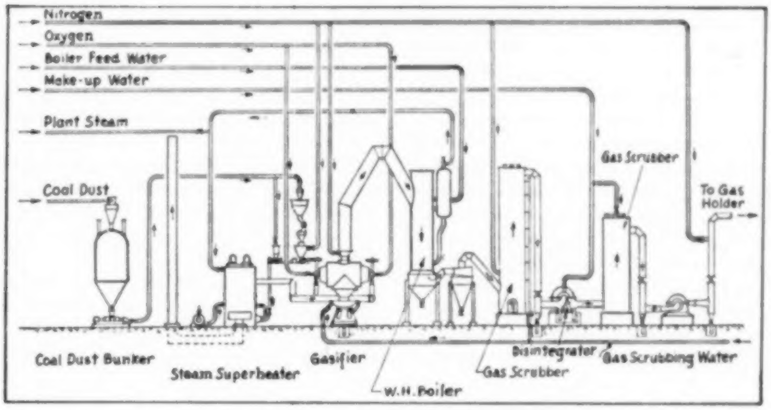


Fig. 1. Diagram of the gasification plant.

ture of finely ground carefully metered coal dust in a definite quantity of oxygen into the reaction chamber of a gasifier that is heated to a high temperature. This process feature, as simple and self-evident as it sounds today, brought with it the successful solution of the problem.

During and after the war, an active interest in the gasification of coal dust began to develop in the United States and, as a consequence, the Bureau of Mines granted a contract to Koppers Co., Inc., Pittsburgh, in 1948 for the erection of a plant for the gasification of coal dust at Louisiana, Mo. This plant was to function as a demonstration plant for the production of synthesis gas to be used in a Fischer-Tropsch synthesis. All the "know-how" data, and basic information of Heinrich Koppers G.m.b.H., Essen, were made available to Koppers Co., Inc., during the erection of the plant, and, of course, to the U. S. Bureau of Mines. The plant was completed and ready for operation within a year's time. It was the first large plant of this type in the world and consequently was subjected to most critical appraisal of experts. Without going into details, it may be recorded that in this plant a first-quality synthesis gas was made for the first time in history from bituminous coal in a single-step process.

The operation of the Louisiana plant indicated certain items that required alteration. However, the operation of the Koppers-Totzek gasifier was successful; the experience formed the basis for the first commercial plant that was directly thereafter erected in Oulu, Finland, for the concern Typpi Oy (i.e., Nitrogen Co.) by Heinrich Koppers. The purpose of that plant was the production of gas for the synthesis of ammonia. A determining factor for the Finnish engineers in making this decision was the fact that the Koppers-Totzek gasifier is adaptable to a variety of fuels.

In this case, it was especially important to consider the use of divers coals, peat, or Bunker C oil as the raw material because the economics of the plant depended upon the price paid for the fuel used. With the exception of peat, Finland has no carbon deposits of its own and is dependent on the world markets for coal and oil.

The Finnish plant was placed in operation in July, 1952, and has been supplying the quantities of gas required for the associated fixed-nitrogen plant ever since. It may be stated, as preface to the discussion of this plant, that no deficiencies or shortcomings have developed that required any fundamental changes. Minor alterations and supplemental repairs have been made as operations were continued.

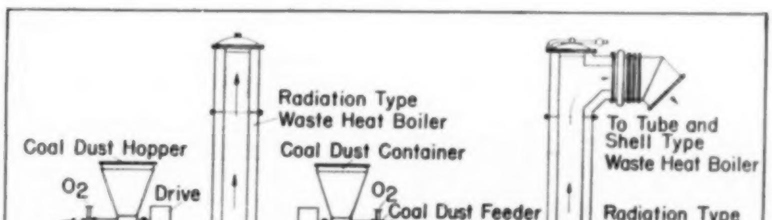


Fig. 2. Gasifier section.

Description of Gasification Plant

Figure 1 shows schematically a general view of the complete gasification plant. It comprises essentially three gasifiers of which one functions as a reserve. Fifty-five tons of coal dust are put through each gasifier per day. The coal presently employed is an Upper Silesian gas coal having a heating value of approximately 10,800 to 11,200 B.t.u./lb., and an ash content of about 16-19%. Construction of facilities for the use of Bunker C oil is now underway, and the use of peat is being considered.

The delivered raw coal is dried in a drying drum to a moisture content of about 7%. It is ground and dried in a ball mill so that it leaves with less than 2% moisture and at a pulverization of 75% through a 200-mesh screen (Tyler).

After leaving the ball mill, the coal dust is delivered to a service bunker, having a capacity of about 1,800 cu.ft., for distribution to the hoppers that are located at each end of each gasifier. The coal dust is delivered directly into the gasifiers by means of a screw conveyor at the outlet of which is a mixing head for mixing the coal dust with oxygen. A uniform delivery of the oxygen and coal-dust mixture is a basic requirement that must be met in order to furnish continuously a constant volume of gas of uniform composition.

After leaving the gasifier the gas-make passes into a waste-heat boiler wherein superheated steam at about 225 lb./sq.in. is produced. The upflowing portion of this boiler is constructed as a radiation boiler. The downflowing portion of the apparatus is a fire-tube boiler wherein the gas flows through the tubes.

The high dust content of the gases requires such an arrangement as described because other types of construction give rise to serious problems with the dust.

A portion of the ash falls into the ash pit of the gasifier and is removed by a rotary grate as is the case with the ordinary Kerpely Producer. The major portion of the ash is carried entrained in the gas stream through the waste-heat boiler and is removed in the lower part thereof, or in a cyclone separator located after the boiler. Depending upon the method of operating the gasifiers and also upon the reactivity of the coal, this residue can contain a greater or less amount of combustible matter that makes its further utilization advisable. It can be fed back into the system and admixed with the new coal or it can be employed for heating the drying drum and the ground coal, or for superheating steam.

A washer cooler is located after the cyclone separator. The gas is scrubbed in this cooler with an adequate quantity of water, similar to standard producer-gas practice. Since the fine dust cannot be completely removed in this scrubbing step, a final clean-up takes place in a disintegrator located after the washer cooler. The disintegrator is followed by a Raschig-ring-packed tower whose main function is to remove entrained wet dust.

After removal of the residual water in a drip pot, the gas passes through an exhauster and is delivered to a gas holder. The gas is then in condition for chemical purification (described later).

In Figure 2 a section through the gasifier itself is shown. At each end of the cylindrical gasification chambers are the two gasifier heads. Their shape results from the necessity of bring-

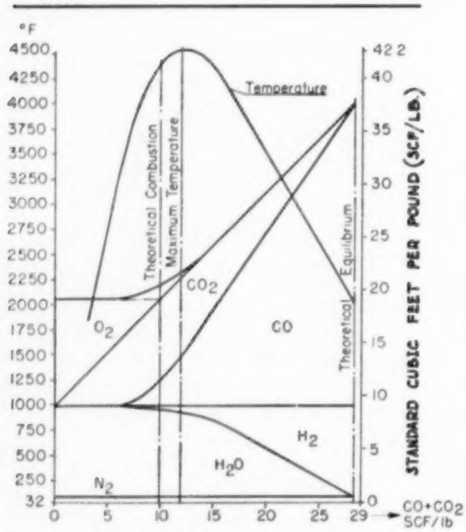


Fig. 3. Diagram of gasification of coke (2% H_2O, 9% ash) with oxygen and steam.

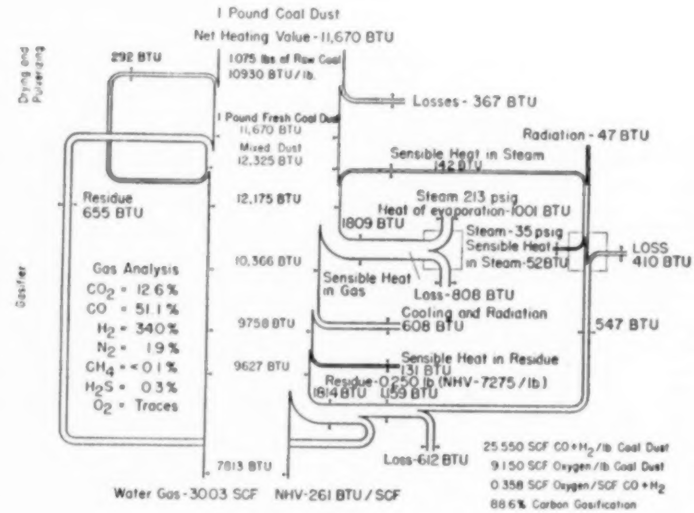


Fig. 4. Heat flow diagram.

Table 1.—Coal Analysis

		Raw Coal	Ground Fresh Coal	Residue	Ground Dust to Gasifier
H_2O	%	8.0	1.11		1.01
Ash	%	14.1	15.2	49.4	18.0
C	%	63.8	68.6	49.8	67.0
H	%	3.94	4.24	0.01	3.89
S (combustible)	%	0.98	1.06	0.49	1.01
N	%	1.14	1.23	0.36	1.15
O	%	8.0	8.6		7.9
B.t.u./lb. (net)		10,800	11,680	7,260	11,300

Table 2.—Analysis of Gas Produced

	Per Cent by Volume
CO_2	12.6
CO	51.1
H_2	34.0
N_2	1.9
CH_4	<0.1
O_2	Traces
H_2S	<0.3
Heating value (net)	274 B.t.u./cu.ft.

Table 3.

Consumption	**U. S. Units**
Raw coal (8% moisture)	110.2 tons
Ground and dried fresh coal (1.1% moisture)	102.5 tons
Recycled gasification residue	9.2 tons
Total ground dust	111.7 tons
Ground dust for drying	2.6 tons
Ground dust to gasification	109.1 tons
Oxygen (98.5%)	1,902 M cu.ft.
Power for gasification plant, incl. coal preparation	7,800 kw.-hr.
Fresh water (added water)	92,400 gal.
Operation—per shift	6 men
Steam (2 atm.)	55.4 tons
Production	
Synthesis gas at standard condition	6,140 M cu.ft.
CO + H_2 in synthesis gas at standard condition	5,200 M cu.ft.
Steam (15 atm., 280° C.)	110.1 tons
Total theoretical residue	31.0 tons
Recycled residue	9.2 tons
Residue lost (removed wet)	9.0 tons
Excess residue	12.8 tons

ing the ignition surfaces of the masonry as close as possible to the outlet of the stream of coal dust and oxygen to ignite the mixture instantaneously as it enters the gasifier. Segregation in the mixture must be avoided so that each dust grain remains distributed in its allotted quantity of oxygen and also so that the reaction on each grain of dust is initiated simultaneously and can progress to the desired degree.

The preparation and *concurrent* injection into the gasifier of the homogeneous mixture of oxygen and coal dust are the most important features in achieving a successful result. By this means there are produced the highest temperatures yielding $CO + H_2$. Experiments have shown that when the stream of oxygen enters the gasifier alongside the stream of coal dust in such fashion that the process of mixing the coal dust and the oxygen takes place simultaneously with the ignition, then, because of the excess oxygen present near the outer parts of the coal-dust stream, a combustion tending toward the formation of carbon dioxide takes place. In this way resulting temperatures would no longer be controllable even with the subsequent but only incomplete reduction of the carbon dioxide produced.

This course of the reactions, in contrast to the countercurrent gasification processes, provides an important advantage. The hydrocarbons are not only cracked, but also are burned to the products of complete combustion, and then reduced. In this way, the gas is free of gum formers and other heavy hydrocarbons. The methane content of the gas is an indication of the degree of the conversion of the hydrocarbons. This is less than 0.1%. In addition, the sulfur compounds appear in such form that they can be removed by simple methods.

The series of curves shown in Figure 3 gives data on the process when gasifying coke with oxygen and steam. They were derived under the assumption that, at the corresponding high temperatures, the transfer of matter through the boundary layer adhering to each coal-dust grain is, as to the time factor, the same as if the starting materials were homogeneously mixed.

Table 4.—Impurities in the Raw Synthesis Gas

Impurities	Quantities
H_2S	125-165 gr./100 cu.ft.
SO_2	0.6-0.8 gr./100 cu.ft.
S_{org}*	16.6-17.4 gr./100 cu.ft.
NO	5-6 p.p.m.
O_2	0.04-0.10 vol. %

* The organic sulfur consists of more than 80% COS and the remainder is CS_2. The gas was free from gum-forming bodies, thiophene and from carbonyl.

Tables 1 and 2 show the analyses of the coal used and the synthesis gas produced at the Typpi plant in Finland. Table 3 shows daily consumption and production figures. The process heat balance is shown in Figure 4.

Special mention should be made of the composition of the gas and its small content of constituents that are corrosive or deleterious for synthesis. Table 4 shows the composition and the amount of the sulfur derivatives in the make-gas as determined by analysis. The surprisingly high quality of the gas is recognizable at once despite the fact that it is produced directly from bituminous coal. The concurrent process, which, as already mentioned, is often unfavorably regarded in heat engineering, is clearly advantageous in respect to the quality of the gas produced.

All the constituents of the coal are subjected to the extremely high-reaction temperatures and are thereby chemically converted. There are no hydrocarbon gum formers in the gas. This makes possible the use of a cheaper purification process than would be the case were the gases less clean. A special purification step for organic sulfur is superfluous since the organic sulfur is changed to hydrogen sulfide in the CO-CO_2 converter before synthesis and this is removed from the gas-make in the scrubbing step for the removal of carbon dioxide. Hydrogen sulfide and nitric oxide are removed in iron-oxide boxes such as are used in the manufactured-gas industry.

The question of safety of operation needs to be impressed on every operator of a new process, and especially when explosive mixtures of coal dust and oxygen are used. This mixture is not explosive, however, if it is introduced into the gasifier at the proper velocity. It can become explosive if the required quantity of coal dust is not supplied; i.e., when the flow of coal dust is reduced by stoppage or the like. In such cases, flashbacks can occur. On the other hand, if the supply of coal failed altogether and oxygen continued to flow into the apparatus, an explosive mixture could develop in the colder parts of the plant. In this connection attention should be called to a special feature of the apparatus: the coal is introduced into a gasifier from at least six injector nozzles. If one or two of these injector nozzles become plugged and the flow of coal stops, the oxygen would react in the gasifier with the gas-make and nothing would occur other than that a poor gas would be produced. To insure against such an eventuality, the following provisions have been made in the construction of the plant.

In order to assure a uniform delivery of coal, the charging of the coal hoppers must be completely automatic. For this reason special coal *feelers* were built into the hoppers and, when the coal level therein dropped sufficiently, these feelers set the coal-conveying apparatus into operation. The coal in the hoppers is stored under nitrogen at a pressure higher than that of the oxygen at the point of injection. By means of a water seal the pressure in the supply hopper is always maintained constant even during the charging of new coal dust. The operating hoppers from which the coal dust is charged to the gasifier are provided with a special *fluffing* device that guarantees a practically continuous supply of the flowing coal.

The temperature in the gasifier serves as an indicator for any irregularities in the gasifier. If the delivery of coal dust is insufficient, the temperature rises. A sharp drop in the coal supplied is indicated by a pressure drop in the injector pipes.

The devices used as the automatic controls depend on temperature in the gasi-

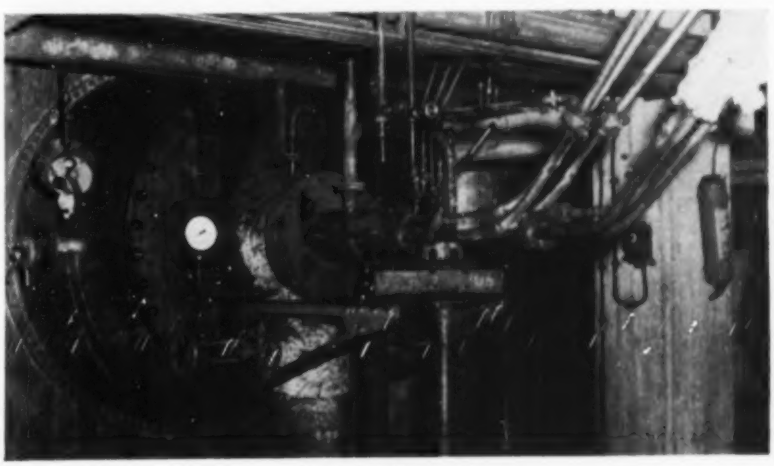


Fig. 5. Gasifier head.

Fig. 6. Instrument and control room.

fier, oxygen content of the gas produced, and pressure drop in the coal-dust-injector pipes.

Precision instruments that control these operating conditions actuate a control system well known to all chemical engineers; i.e., by means of a source of power, in this particular instance oil-pressure, the system is held open or closed in normal operation. When disturbances occur, the oil pressure on the divers shut-off apparatus changes, thereby causing the oxygen supply to be shut off, the conveying equipment for coal dust to be shut down, and the entire gasification system to be purged with nitrogen. The whole adjustment is so sensitive that even with small fluctuations in the system the entire automatic-control system responds, and should electric power completely fail, the controls immediately shut down the entire plant, and thus in all respects safe operation of the whole gas-producing installation is guaranteed.

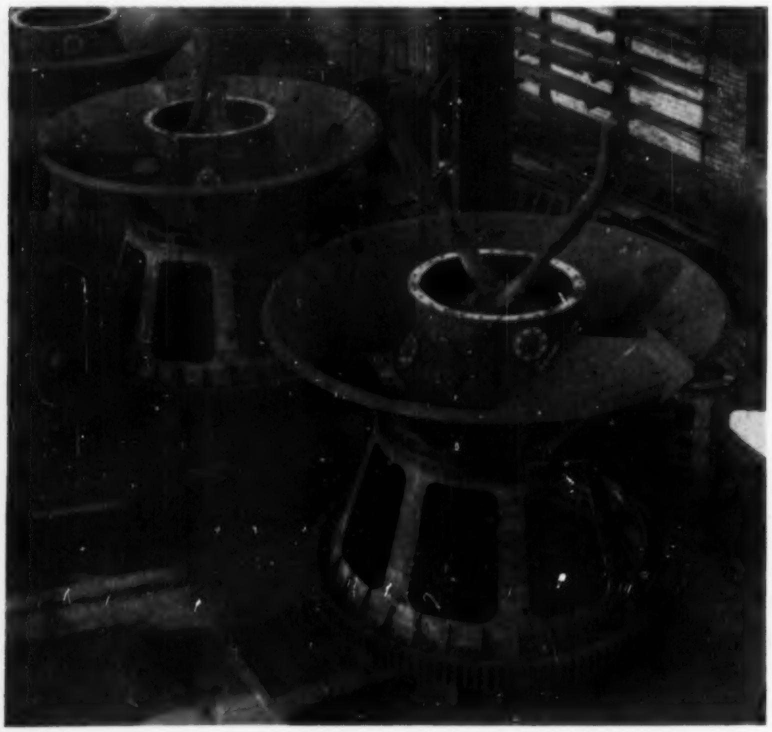


Fig. 7. Ash-removal pan in shop.

The operating force per shift comprises:

1 Roving foreman
1 Control-room operator
1 Gasifier operator
1 Ash-and-residue operator
1 Blower-room engineer
1 Coal-handling man

Figure 5 shows the external arrangement of a gasifier head, with its three oxygen-coal feed pipes. Each gasifier head and each pipe for oxygen and coal dust has its own measuring instruments and control elements.

Figure 6 shows a general view of the control room. It is possible for the operator clearly to inspect and control the entire operation from that point. In addition, the valves for all the gas lines are in the instrument-control room so that when required the operator can change over to manual operation.

Figures 7 and 8 show the ash-removal apparatus and the driving equipment before and after assembly.

Figure 9 shows one of the gasifier shells as it came from the shop.

Figure 10 shows the coal-feed bin and metering screws at the end of which the oxygen picks up the coal dust.

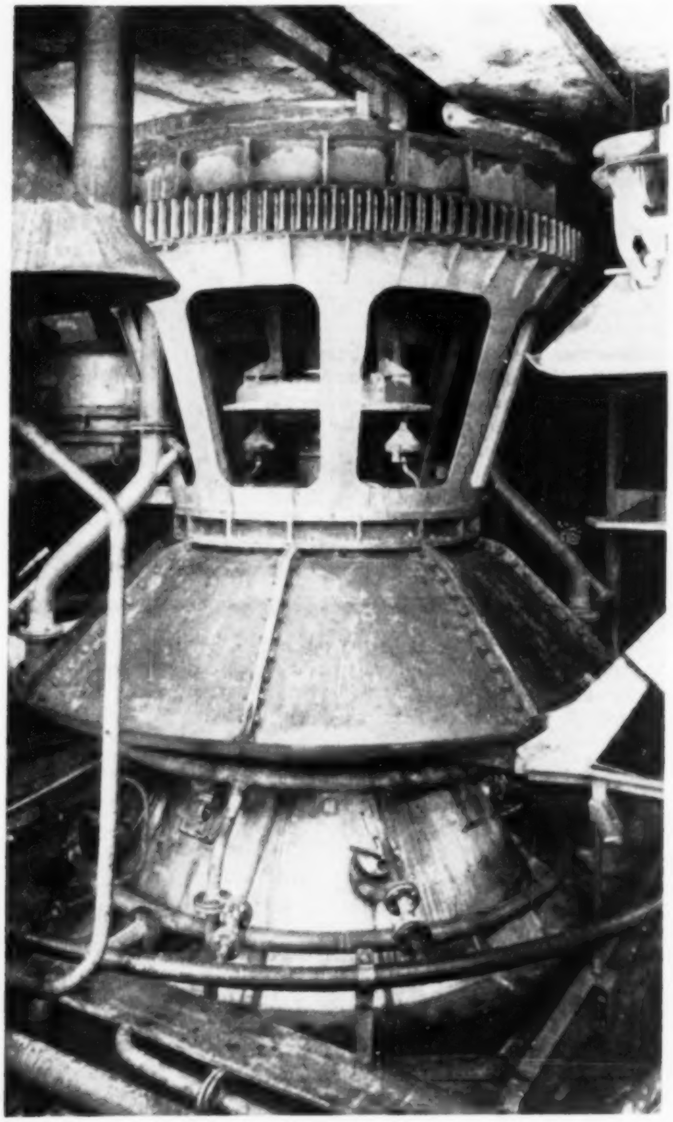
Because of the weather conditions in Finland the entire gasification plant is housed in protective buildings. Figure 11 shows an exterior view of these buildings.

This plant has been in operation since midsummer 1952, and at no time has the ammonia plant been shut down because of operational difficulties in the gasifier plant. Typpi Oy, the client, must be well satisfied because it has drawn plans to double the present gasification capacity. Two other plants are now under construction, one in France and one in Japan.

In lands having available any type of carbon-bearing fuel, the Koppers-Totzek system of coal gasification makes it possible to convert them into synthesis gas for the manufacture of synthetic chemicals, liquid fuels, and city gas.

It will be obvious that costs and selling prices vary widely depending upon the location of the plant and other factors and so it is not now possible to generalize about the over-all economics of this Koppers Totzek process. As more practical experience is gained and still further improvements are incorporated, this development will have wider application, not only in the so-called undeveloped countries, but also in the more industrialized areas of the world.

Presented at A.I.Ch.E. St. Louis meeting by Fred Denig, Koppers Co., Pittsburgh, Pa.



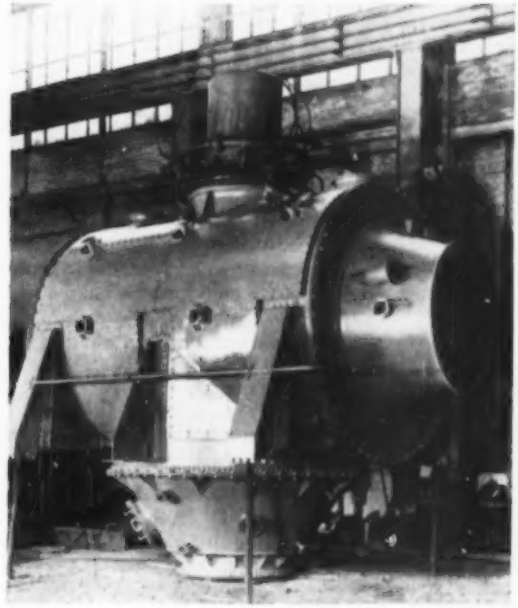
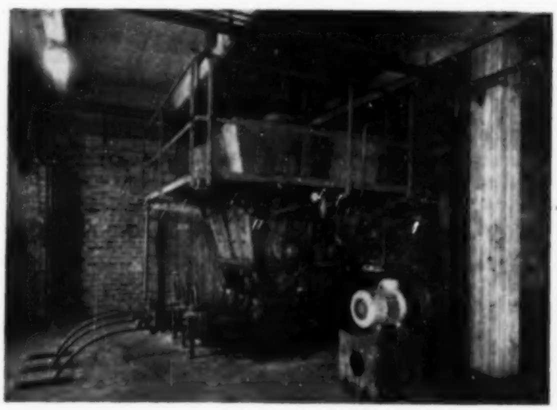


Fig. 8. (*Top left*) Ash-removal equipment in place.

Fig. 9. (*Top right*) Gasifier shell in shop.

Fig. 11. (*Bottom right*) View of the Typpi Oy plant.

Fig. 10. (*Bottom left*) Coal feed bin and metering screws.



MIXER-SETTLER

Extraction Equipment

Extraction equipment of the multistage mixer-settler type provides the intensive contact between phases that is required in processes involving complex compounds of the heavy metals. In this report the design and operation of the known types of mixer-settler units are discussed, and a detailed description of mixer-settler units constructed and installed in the Radiation Laboratory is given.

Milton W. Davis, Jr., Thomas E. Hicks, and Theodore Vermeulen   University of California, Berkeley, California

As most extraction operations are limited by equilibria which do not allow complete separation in a single stage, they are performed countercurrently in contacting equipment equivalent to several equilibrium stages. The equipment is diversified partly because of variations in the properties of each of the two liquid phases, in the rates of interphase transfer of the solutes, and in the ease of isolating the phases after they have been contacted.

Three distinct types of continuous-flow countercurrent extraction equipment are known:

1. Equipment in which the relative vertical flow of the two phases under gravity (or the relative radial flow in a centrifugal field) accomplishes the contact between phases. Vertical columns equipped with spray nozzles, perforated plates, or ring or saddle packing are the best known examples. An annular column with rotating central shaft may be considered a variation of this type.

2. Equipment in which interface for transfer is obtained by oscillatory flow of the liquids passing through the contact equipment, as in pulsed packed columns and pulsed perforated-plate columns.

3. Equipment of the mixer-settler type in which thorough contact is achieved in individual stages by the mechanical action of an impeller or a mixing jet, and the phases are then separated by gravity or by centrifugation before entering the adjacent stages. Many variations in design are possible.

a. A common shaft for all stirrers, vs. an individual shaft for each stage. The use of a common shaft apparently requires a more direct interconnection between the stages; however, this type appears less expensive both to construct and to maintain.

b. Vertical vs. horizontal arrangement of the stages. In general the vertical units possess a common shaft and the horizontal units do not. The transfer between stages almost always occurs by gravity in the vertical type, but it may occur either by gravity or by pumping of one or both streams in a horizontal unit.

c. Cocurrent vs. countercurrent settling within each stage. In cocurrent settling the emulsion produced in the mixing chamber passes to a single settling chamber, from which the separated phases move to the adjacent stages. In countercurrent settling the emulsion spreads into two settling chambers, one above and one below the mixing chamber. From the upper settler the light phase is carried to the next higher stage and the heavy phase is returned to the mixing chamber; from the lower settler the heavy phase is withdrawn and the light phase is returned to the mixer.

d. Control of the ratio of phases in the mixing chamber independent of the flow rates, which is permitted by some designs. This allows the residence time to be increased for the phase in which the slow transfer step occurs. This phase control can take place only if the pressure distribution in the mixing chamber is uniform enough to permit the density of fluids to cause an equalization of densities between mixing and settling chamber; then the control of the heavy phase level in the settling chamber will determine its volume in the mixing section. If the emulsion entering the settling chamber is uniform with that in the mixing chamber, then back flow of one phase must occur from the settling chamber to the mixing chamber to permit the phase ratio to be independent of flow rate. Therefore, if the organic-to-aqueous phase ratio is greater than the organic-to-aqueous flow ratio, a certain amount of countercurrent settling or recycling of the organic phase must be postulated, even though the over-all flow to each settling chamber is concurrent.

Twelve industrial designs for mixer-settlers are discussed in this section. A summary of the main features is shown in Table 1.

Vertical Extraction Columns

McKITTRICK COLUMN (1939)

The apparatus in Figure 1 is a vertical mixer-settler with a common shaft for all stirring paddles (*7*). In each stage the liquids flow cocurrently to the settling chamber. The mixing paddles are mounted on a vertical shaft (8) extending the height of the column through the horizontal partitions (2), the partitions being provided with suitable packed bearings around shaft (8) to prevent the flow of fluid between mixing stages. Each adjacent pair of chambers is connected by a small valve (11), which is used for venting

Milton W. Davis, Jr., is with E. I. Du Pont de Nemours and Co., Explosives Dept., Savannah River Plant, Aiken, South Carolina; Thomas E. Hicks is associate professor of chemical engineering at U.C.L.A.

Table 1.—Comparison of Mixer-Settler Designs

Inventor	Figures	Type of stirring	Type of settling	Arrangement	Driving force for flow	Relation of phase ratio (in mixing chamber) to over-all flow ratio
McKittrick	1, 2,	Common shaft	Cocurrent	Vertical	Gravity	Independent
Schöneborn	3, 4, 5, 6	Common shaft	Cocurrent	Vertical	Gravity	Dependent
McConnell	7	Common shaft	Cocurrent	Vertical	Heavy phase pumped, light phase by gravity	Independent
Scheibel	8	Common shaft	Countercurrent	Vertical	Gravity	Dependent
Bottaro	9, 10, 11, 12	Common shaft	Countercurrent	Near-vertical	Gravity	Dependent
Othmer	13, 14	Common shaft	Countercurrent	Vertical	Gravity	Independent
Van Dijck	15, 16	Common shaft or individual stirrers	Countercurrent	Near-horizontal	Gravity	Either dependent or independent
Holley	17, 18	Individual stirrers	Countercurrent	Near-horizontal	Gravity	Independent
Mensing	19, 20	Individual stirrers	Countercurrent	Horizontal	Both phases pumped by mixer	Independent
Edeleanu	21, 22	Individual stirrers	Cocurrent	Horizontal	Light phase pumped, heavy phase by gravity	Dependent
Standard Oil Development	23	Individual stirrers	Cocurrent	Near-horizontal	Gravity	Independent
Gordon	24, 25, 26	Individual stirrers	Cocurrent	Horizontal	Both phases pumped by mixer	Dependent

air from the apparatus or draining liquid to the lower chamber.

Elongated horizontal settling tubes (*18, 19, 20,* and *21*) are connected to each mixing chamber at a level near the middle of the chamber. These cylindrical settling tubes are entirely external to the column structure that contains the mixing chambers. The settling tubes are connected to T-fittings (*22, 23, 24,* and *25*) opening into vertical conduits which connect with the upper and lower parts of the mixing chamber. The heavy-liquid take-off from the bottom stage is controlled by valve (*34*) and actuated by a liquid-level controller (*36*), operable to cause only heavy liquid to discharge at the bottom. The light-liquid discharge at the top of the column is controlled by a pressure-actuated valve (*37*) arranged to maintain a predetermined pressure in the system. The heavy feed to the column enters at the top through line (*16*); the light feed, at the bottom through line (*17*).

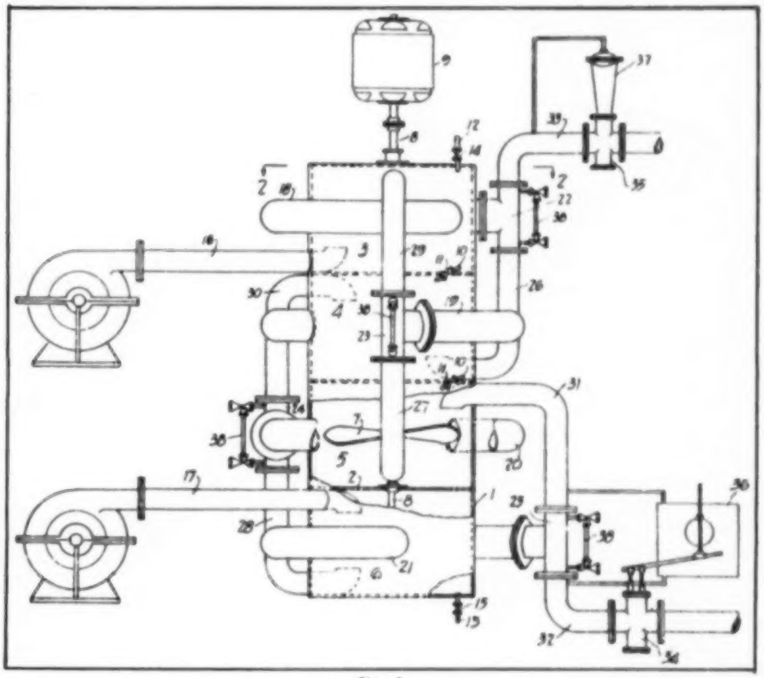


Fig. 1.

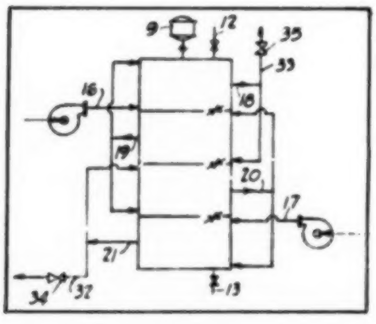


Fig. 2.

Figure *2* shows a schematic view of the flow throughout the column. The over-all flow is countercurrent; the settling flow is cocurrent. The phase ratio in the mixing chamber is essentially independent of flow rates; adjustment of the phase ratio maximum transfer rate is possible. Moreover, the relative volumes of mixing and settling chambers may be varied widely

The column is assembled by bolting the mixing sections together by external flanges. Each mixing paddle must be fixed to the common shaft before the next mixing chamber is bolted into place. After the mixing chambers are assembled, the settling chambers may be attached externally as piping connected to a T leading to the next higher and next lower mixing chambers, as shown in Figure 1.

SCHÖNEBORN COLUMN (1934)

Figure 3 shows a vertical mixer-settler with a common shaft for all

mixers (*11*). Over-all flow is by gravity, the liquids flowing cocurrently to the settling chambers. The mixing zone is relatively small, and its phase ratio is a function only of the flow rates.

The heavier liquid enters at the top through pipe (13) and after passing through the column leaves through pipe (4); the light liquid enters through pipe (9) at the bottom and leaves through pipe (16). Each of the mixing sections (1) is separated from the section above and below by horizontal partitions with central openings, through which shaft (21) passes and the light and heavy liquids flow between stages.

The partition or floor of each mixing section is provided with an upper and lower projection. The upper projection (37) in Figure 4 serves to dam the heavier liquid settling in the section above partition (35). As fresh liquid flows into the upper section, the heavier liquid flows over projection (37) through opening (36) into the next lower mixing section. The lower projection (38) serves a similar purpose for the lighter liquid. On projection (38) are four tubular extensions (39), which carry the light liquid collecting under partition (35) into the next higher mixing section without hindering downward movement of the heavier liquid.

Each mixing section is provided with flanges (1a) by means of which it is bolted to adjacent sections.

Figures 4, 5, and 6 illustrate the design of the mixing device consisting of an inner supporting member (42) secured on the shaft (21) by a key (41), and inside the housing (43). When the stirrer is rotated, fresh unmixed liquid flows into channels (44 and 44a) from the sections above and below. The centrifugal force causes the mixed liquids to be thrown out of the side opening (44b) into the settling chamber, where after separation they are directed to adjacent stages.

A comparison of the McKittrick and Schöneborn columns shows that the settling chambers are external to the column in the McKittrick type but internal in the Schöneborn type.

McCONNELL COLUMN (1937)

A vertical mixer-settler with a common shaft for all mixers (*6*) is shown in Figure 7. The heavy phase is pumped from stage to stage, the light liquid flows by gravity, and the liquids flow cocurrently while settling. The ratio of phases in the mixing chamber is relatively independent of flow rate because the interstage pumping may be

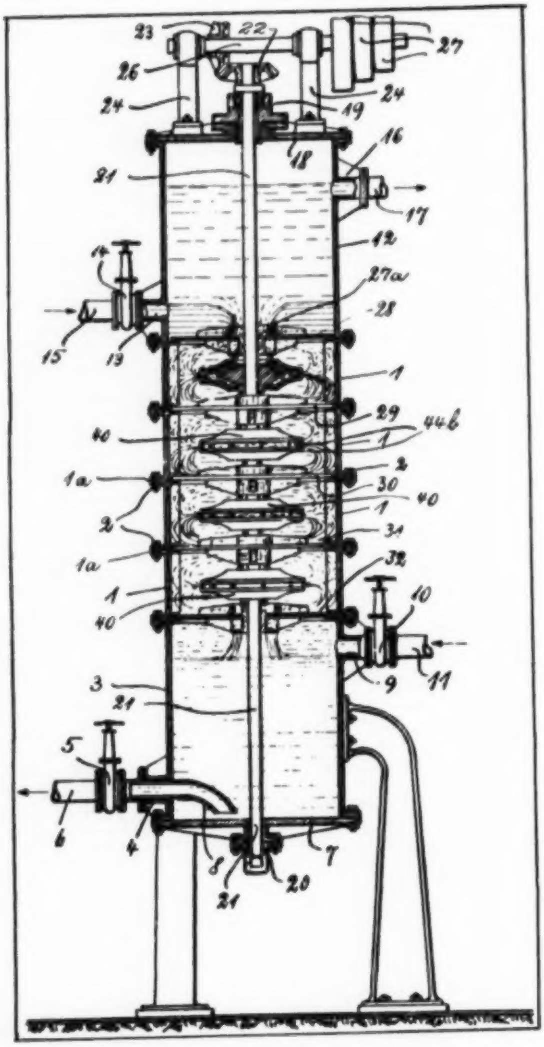


Fig. 3.

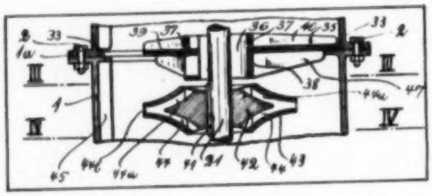


Fig. 4.

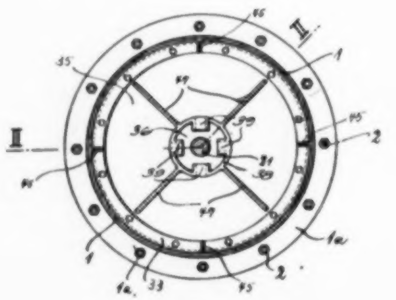


Fig. 5.

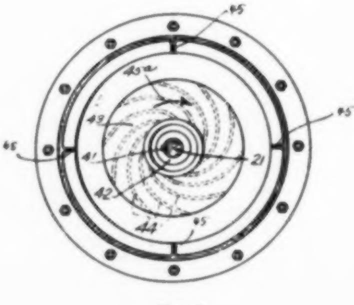


Fig. 6.

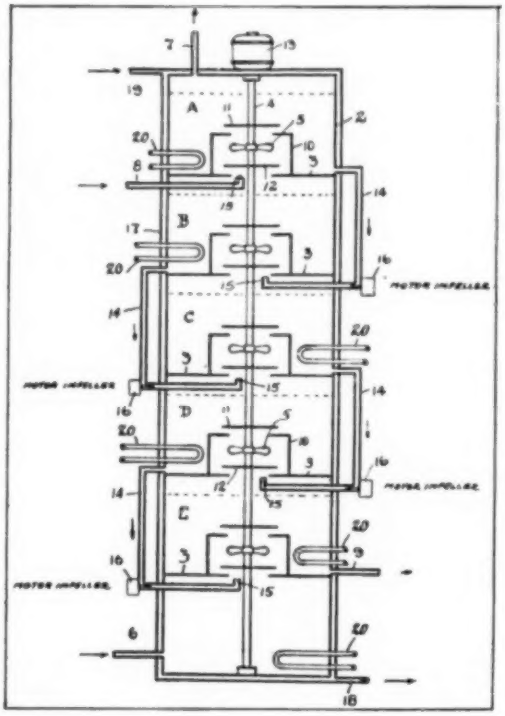


Fig. 7.

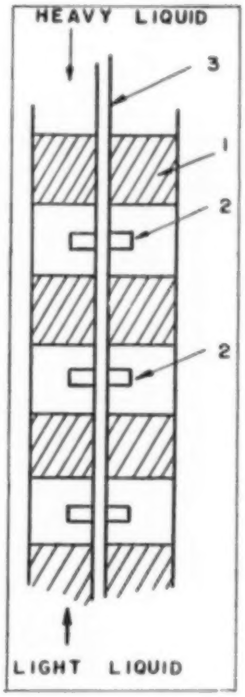


Fig. 8.

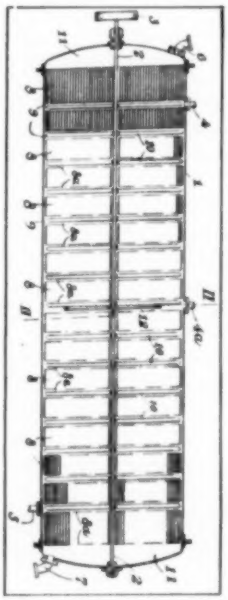


Fig. 9.

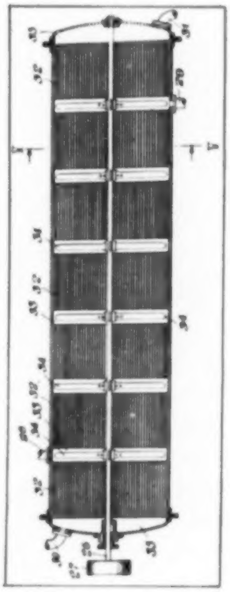


Fig. 11.

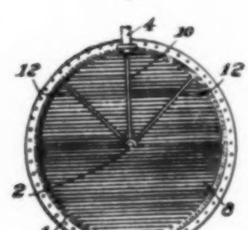


Fig. 10.

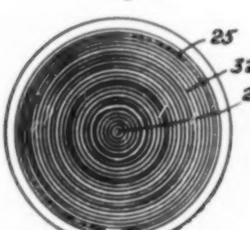


Fig. 12.

accelerated or retarded to allow one of the phases to accumulate. The lighter liquid is fed into the inlet (6) at the bottom, and the heavier liquid is fed into inlet (8) at the top. After the liquids pass countercurrently through the tower, the lighter liquid is discharged at the top outlet (7), and the heavier liquid is discharged at the lower outlet (9). In travel through the apparatus, the liquids are mixed together in the impeller housings (10); passing through the top, they enter the settling chamber, where they separate and maintain an interface at the upper part of the compartment. The heavier phase is then pumped through outlet (14) to the bottom of the next lower mixing section, where it enters with the lighter phase moving up from the section beneath. Individual temperature control in each stage is provided by coil (20).

SCHEIBEL COLUMN (1946)

The vertical mixer-settler in Figure 8 has a common shaft for its agitators, and the over-all flow is by gravity (*10*). Mixing sections are alternated with settling sections packed with Raschig rings or other packing material, in which the liquids undergo countercurrent flow. A column of this type can be run with either phase continuous, and therefore the ratio of phases in the mixing zone can be altered. Stage efficiencies of over 100% due to material transfer in the packing in addition to that in the mixing section have been observed; as shown experimentally, a packed section larger than the mixing section leads to better stage efficiencies.

BOTTARO COLUMNS (INCLINED)(1940)

The nearly vertical mixer-settlers in Figures 9 and 11 have common shafts for the agitators, and the liquids flow in a countercurrent manner while settling as in the Scheibel column (*2*). The over-all flow is by gravity with the heavy liquid fed at the top at entrance (4), and the light liquid fed at the bottom at entrance (5). In Figure 9 the settling zone is formed of flat plates (8). The vertical position of operation is excluded in this design since it is desirable to have the fluids pass each other in layers or sheets rather than in drops. The settling plates are placed very close together to give more complete settling with some additional material transfer. Figure 10 shows a cross section at II-II.

In Figure 11 the principles are the same except that the calming section consists of cylindrical shells attached to the rotating shaft, which are purported to enhance the separation of

phases by centrifugal force. A cross section at V-V is shown in Figure 12.

OTHMER COLUMN (1935)

The vertical mixer-settler shown in Figure 13 has a common shaft for its agitators and the over-all liquid flow is by gravity (*9*). The two phases settle in a countercurrent manner. The mixing chambers are separated from each other by hollow cones with fins dividing the volume outside and inside into four sections for improved settling. The stirring shaft passes through the apex of these cones with some space left for upward flow of light liquid. The heavy liquid passes down the outside of the cones and through small openings to the next mixing chamber. Figure 14 is a detailed drawing of this cone.

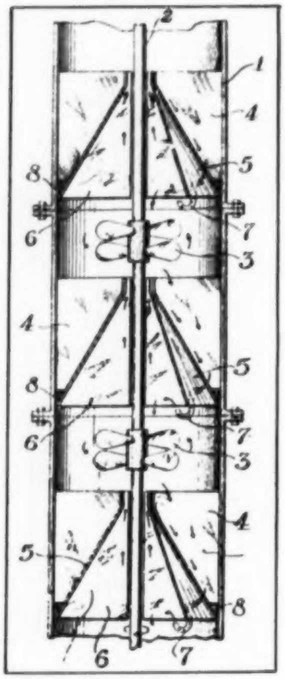


Fig. 13.

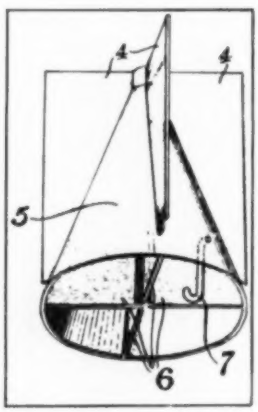


Fig. 14.

Horizontal Extractors

VAN DIJCK EXTRACTOR (1941)

The fluids flow countercurrently by gravity in all sections of the nearly horizontal mixer-settler shown in Figure 15 (*13*). It is a cylindrical shell with supports (2 and 3) subdivided by partitions (4a, 4b, 4c, 4d, 4a′, 4b′, 4c′, 4d,′ etc.) formed of perforated plates or sieves to provide alternating mixing and settling zones. A common shaft (12) carries agitators (13a, 13b, 13a′, and 13b′) such as propellers, paddles, or rods, and is turned by pulley (14) to provide mixing in the mixing zones.

The flow through the apparatus, effected by gravity alone, depends upon the tilt of the apparatus and upon the density differences of the two phases. Valves (15 and 16) control the feed to and outflow from the end settling zone (*7*); valves (17 and 18) similarly control the outflow from and feed to end settling zone (*8*). The light liquid enters through valve (15), and the heavy liquid enters through valve (18).

HOLLEY EXTRACTOR (1934)

The horizontal mixer-settler shown in Figure 17 has an individual stirring shaft for each stage, with a recirculation line from the settling chamber to the mixing chamber (*5*). The rate of recirculation, controlled by a valve in the recirculation line, allows the rate of the ratio of phases in the mixing chamber to be varied. The over-all flow occurs by gravity.

The light liquid enters at (y) and leaves the apparatus at (*y′*) after passing through several mixing stages (four are shown). Heavy liquid enters and leaves at (z). The emulsion from the mixing chamber flows through (d) to the settling chamber, where the heavy phase is partly recirculated to the mixing chamber through (e), and partly sent to the next mixing section through bottom connection (g). The light phase passes from each settling section to the next mixing section through connection (f).

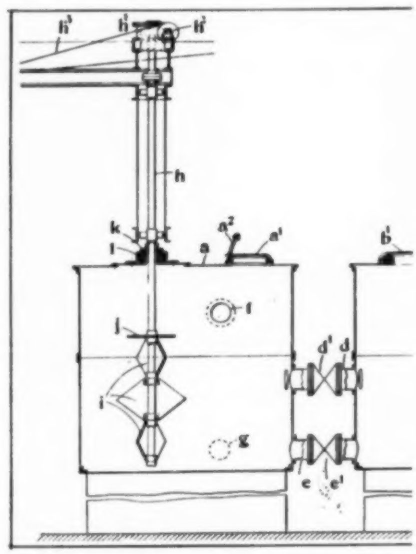


Fig.

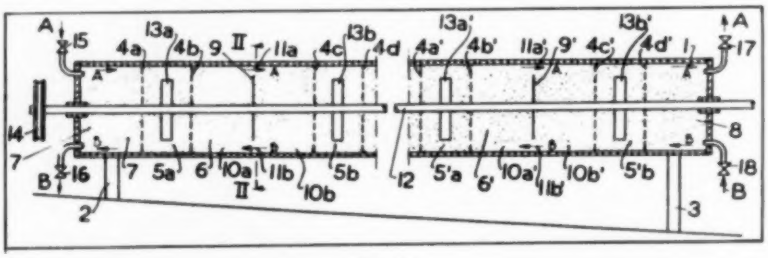


Fig. 15.

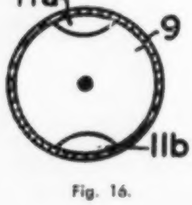


Fig. 16.

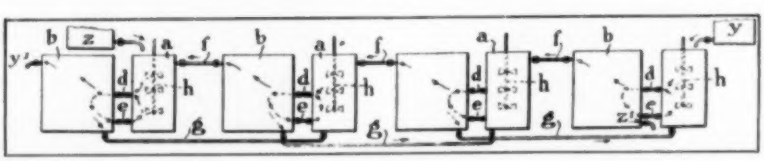
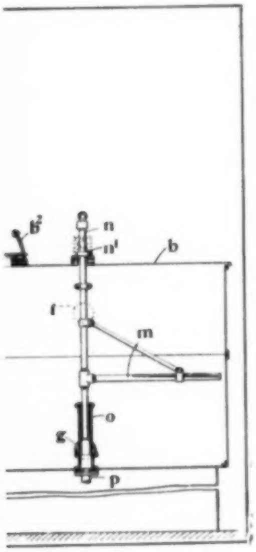


Fig. 17.

The recirculation device is intended as a means for maintaining a fixed ratio of light to heavy liquid in the mixing chamber irrespective of the rate at which the respective liquids are fed. By providing a number of connecting pipes between the respective mixing and separating vessels and by controlling the flow through them, the amount of liquid recirculated to the mixing vessel may be varied widely to meet varying practical requirements. The counterflow of the liquids is effected by gravity alone.

In Figure 18 the mixing chamber is shown in detail. A vertical spindle (h) is the mixing shaft. Vanes or blades (i) are mounted upon the spindle, one beneath the other and at an angle one to the other. The top blade is surmounted by an antivortex disk (j), transversely mounted upon the vertical spindle (h), and the spindle itself is located off center to help prevent vortex formation. The mixing vessels may be provided with cover cups (k) secured to the spindle, which extend downward into an annular sealing trough (l) mounted on the top plate.

Figure 18 also shows a device for removing foreign matter that may accumulate at the interface in a settling chamber. For this purpose a horizontal radial arm (m), open or slotted, may be mounted on a vertical spindle (n), the lower end of which is mounted in a tubular socket at the bottom. The socket is connected to an outlet pipe controlled by a valve. By vertical adjustment of the upper end of the hollow rod or spindle, the horizontal arm may be set at the interface; then, when the hollow rod rotates, the arm will sweep the plane of the interface, forcing any accumulation of solid matter at the interface to move with the entraining liquid into a skimming tank.



18.

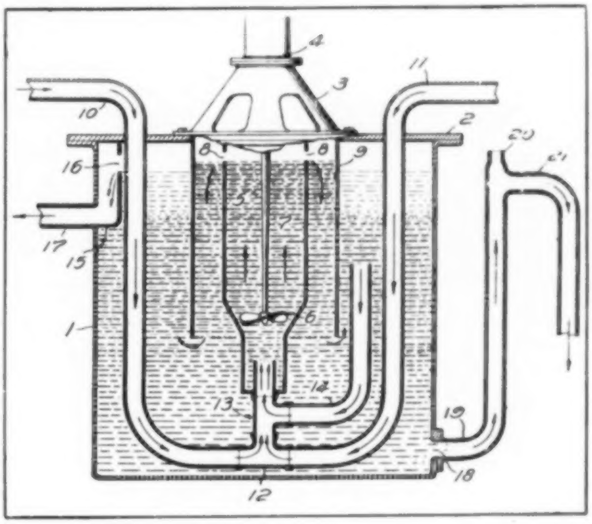


Fig. 19.

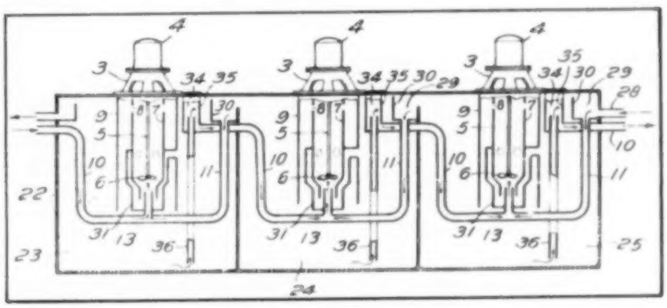


Fig. 20.

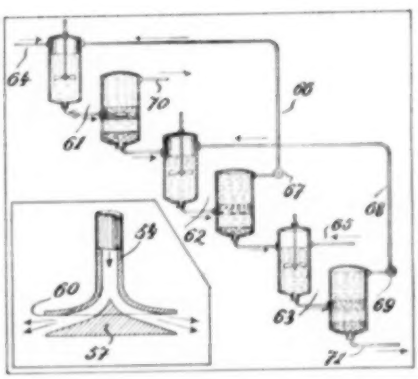


Fig. 21.

Fig. 22.

MENSING EXTRACTOR (1946)

The horizontal mixer-settler in Figure 19 has individual stirrers and countercurrent settling flow controlled by a recycling tube which may be adjusted in height so as to recycle either emulsion or settled phases (*8*). The two phases are pumped into the mixing section by the action of the mixing propeller. The heavy liquid level in each chamber is set by an adjustable inverted U.

Fluid to be extracted enters through conduit (10), and extracting solvent enters through conduit (11). They mix in conduit (13), and flow to the mixing space enclosed by sleeve (7). The propeller, designed for upward thrust, forces the emulsified mixture up through the sleeve, out through openings (8) into the annular space between sleeve (7) and baffle (9), down through the annular space, under the lower edge of baffle (9), and out into the main space of chamber (1). In this main chamber the emulsion from the mixing section breaks, and the respective phases overflow through opening (16) and out of the chamber through (17) or fall through opening (18) and flow up through conduit (19) and down through conduit (21). By adjusting the height of the inverted U formed by conduits (19) and (21), the height above the bottom of the chamber, and therefore the volume of the heavy phase, may be controlled.

It is apparent that the flow capacity through sleeve (7) and the annular space between the sleeve and baffle is potentially much larger than through

feed conduits (10) and (11). Conduit (14) is used to recycle unseparated or partially separated emulsion, and it is desirable to make the inlet adjustable in height to control the content of the recycle stream.

Figure 20 shows a multicompartment apparatus based upon the design of Figure 19. A large chamber (22) is divided into three chambers of equal size, each equipped as just described. Each chamber is provided with a conduit (10) for introducing the fluid to be extracted. The fluid chamber (23) enters from the outside, and chambers (24) and (25), from the immediately preceding chamber. Each of the chambers is also provided with a conduit (11) for introducing solvent in a direction countercurrent to the flow of material to be extracted. The solvent is introduced through conduit (28) into a pocket (29) formed by baffle (30) and is carried from the pocket through a conduit into the T connection below the impeller. The solvent flows from one chamber to the next over the dividing wall, which does not extend the entire height of the chambers.

In order to obtain more uniform recirculation, conduit (14) has been replaced by the following alternative arrangement. In each chamber a third concentric baffle (31), located between sleeve (7) and baffle (9), extends about half the height of sleeve (7). This baffle is closed at the top by an annular plate. Admission into the annular space between sleeve (7) and baffle (31) is by means of several short conduits (33) spaced approximately equally around the baffle.

The liquid interface within each chamber is controlled by adjusting the distance to which conduit (36) extends up into pocket (34).

EDELEANU EXTRACTOR (1927)

The horizontal mixer settler with individual stirrers shown in Figure 21, has the two phases settling in cocurrent flow (*3*). The light phase is pumped up to the next mixer; the heavy phase flows by gravity. The heavy liquid entering by line (64) and the light liquid by line (65) proceed in a countercurrent flow pattern. Figure 22 shows the method for introducing emulsion into the settling chamber with minimum disturbance to the contents of the chamber.

Historically this is one of the earliest designs. In its inherent simplicity it is the forerunner of many of other designs, including especially the Holley and Mensing models.

STANDARD OIL DEVELOPMENT CO. EXTRACTOR (1949)

The horizontal mixer-settler shown in Figure 23 has individual stirrers with the settling phases flowing cocurrently (*12*). In this unit a positive control of the phase ratio in the mixing chamber is maintained by means of a weir on the discharge side of the mixing stage. A large unit of this type would contain a number of stages side by side but turned 180° with respect to one another in a horizontal plane. This permits a very compact boxlike construction with the interstage flow accomplished by means of openings cut in the partitions between stages.

The over-all flow through the unit is countercurrent, but in each stage flow is cocurrent. Each stage consists of an antechamber, a mixing zone, and a settling section. The antechamber is a quiescent zone into which the light and heavy phases enter before passing through a horizontal slot into the mixing zone; it seems to prevent back mixing by isolating the interstage ports from the direct action of the mixing element. It also permits a perfectly symmetrical design for the mixing zone, in that the phases after mixing pass to the settler through a second horizontal slot which is identical with the first one. The horizontal slots are protected from the direct action of the mixer by shielding baffles.

At the end of the settler the separated phases resume their countercurrent flow pattern by going in opposite directions to the adjacent mixer antechambers. Flow through the unit is by

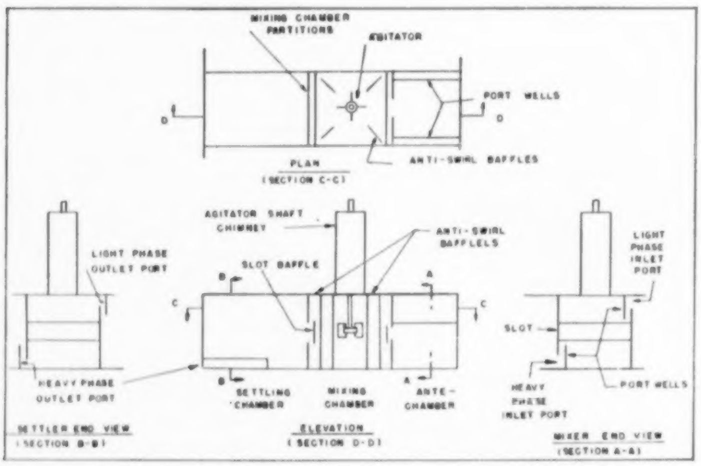


Fig. 23.

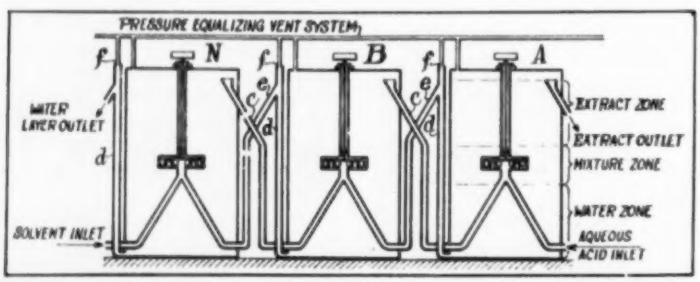


Fig. 25.

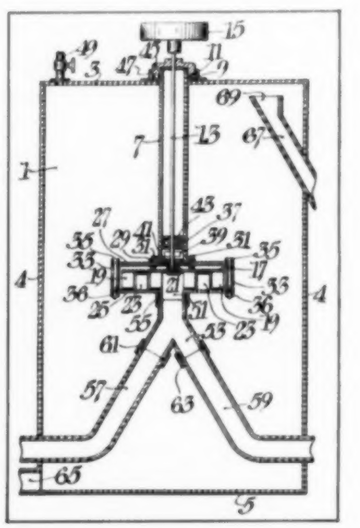


Fig. 24.

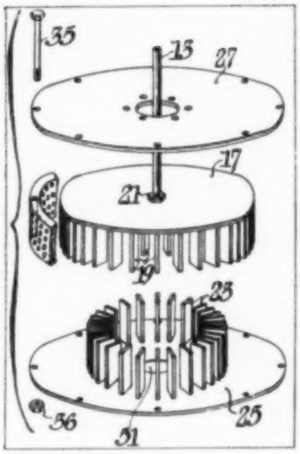


Fig. 26.

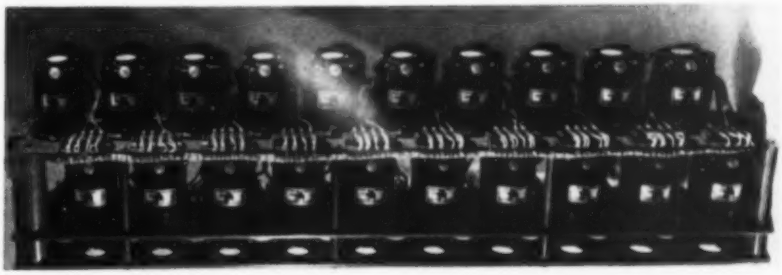


Fig. 27.

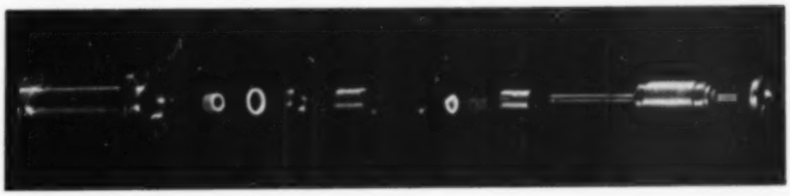


Fig. 28.

gravity; the head required for flow is obtained by tilting the contactor; hence no interstage pumps or valves are required.

GORDON EXTRACTOR (1939)

The horizontal mixer-settler shown in Figure 24 has individual stirrers with the settling phases flowing cocurrently (4). The two phases are pumped into the mixing chamber by the mixing paddle, the ratio of phases in the mixing zone being dependent upon the flow rates. The mixed fluids are thrown through porous plate (33) into the large cylindrical or cubic settling chamber to break the emulsion. The light fluid overflows through (69); the heavy fluid leaves through (65). In Figure 25 a pressure equalizing system is shown, attached to the heavy fluid exit. An adjustable valve at (f) may be used to control the effective height of the overflow in order to maintain the correct ratio of water layer to solvent layer within the bank. Figure 26 shows details of the stirring device.

Because the mixing chamber is contained completely within the settling chamber, this extractor is basically similar to any one stage of the Schöneborn column.

Design of a Continuous Countercurrent Horizontal Mixer-Settler Unit

Two twenty-stage horizontal mixer-settlers have been designed and constructed to study the laboratory-scale separation of radioactive materials. This particular type of equipment was chosen because of lack of vertical space and because of favorable experience with it by the Argonne National Laboratory (*1*) and the Standard Oil Development Company (*12*).

In order to have all construction materials resistant to both strongly acid aqueous solutions and organic solvents, stainless steel is used with Teflon as a gasketing material and Kel-F for windows. Individual motors for stirring each stage are employed in preference to a belt drive because of mechanical simplicity. The shafts of these stirring motors enter the stirring chamber through liquid-tight seals. Alternative construction with open stirrer wells would increase the liquid hold-up in each stage during operation in a tilted position. In addition, seals reduce the hazard from overflow or spray of radioactive solutions. The extractor and accessories, mounted behind radiation shielding, are equipped for remote control.

STIRRING MOTORS AND SHAFT SEALS

The stirring motors are variable-speed, 115-v. D. C./40 hp., 3,350 rev./min. continuous-duty, type-NSH 13, made by the Bodine Electric Co. The mounting for a bank of twenty of these motors is shown in Figure 27.

The liquid-tight seals on the agitator shafts were built by the Crane Packing Co. Each seal proper consists of a fixed ceramic ring and a rotating carbon ring with ring faces held together by spring tension for rotating contact. The ceramic ring is held in the shaft housing; the carbon ring is secured to the rotating shaft. The carbon ring is supported by a Teflon ring, which fits snugly over the shaft and is held in place by a spring which fits into the cover. The cover is held on the shaft by a set screw. The carbon ring is secured by small steel pieces peened over the ridges of the cover. Figure 28 is an exploded view of these assemblies.

The ceramic ring fits in a well at the bottom of the shaft housing; the Teflon ring, which fits snugly over the outside of the ceramic ring, is held in place and pressed tightly around the ceramic ring by a brass bushing. The pressure is supplied by the threaded steel ring which screws down on the brass bushing.

Because considerable heat is liberated by the friction of the two faces, it is necessary to have the solution close enough to the faces to lubricate and cool them.

AGITATORS AND FLOW DESIGN

In a prototype mixer-settler having a single stirred stage a phenomenon termed *pullover* occurs if an on-off type of liquid level control is used to regulate the discharge of the heavy phase from the bottom of the prototype. When the air-operated valve opens, a rapid surge of the heavy phase through the mixer-settler occurs. To avoid possible back mixing of the light phase, an open by-pass is provided.

Back mixing, which was particularly

difficult to eliminate, is the transfer of material from the mixing chamber of one stage to the adjacent settling chamber which normally feeds into it. Various shapes of baffles were tried as shielding for the entry ports of the light and heavy phases to the mixing chamber. Back mixing occurs in all designs tested except in those with an antechamber for entering streams. The walls of the antechamber must extend the entire height of the mixing chamber to shield the entry ports completely from the direct action of the mixing device.

The design of the stirring paddle selected is a two-bladed flat paddle, 0.875 in. in diam. and 1.50 in. wide, which is satisfactory over the whole range of stirring speeds. The flow rate of the light phase was varied from zero to 100 ml./min.; the flow rate of the heavy phase, from zero to 80 ml./min. No back mixing was observed in the prototype under these conditions at a stirring speed up to 3500 rev./min.

The baffle design (Figure 29) used in the bank of mixer-settlers seems to cause no pumping action and no blocking of flow, in agreement with the operation of the prototype. Emulsified liquid leaves the mixing chamber through a vertical slot in the baffle. It then hits the second baffle and begins to separate into phases, which run into the settling chamber through the rectangular slots at the top and bottom. After entering the settling chamber the light phase flows to the mixing chamber above it and the heavy phase to the mixing chamber below it.

Air vents are provided in all baffles so that air will flow successively from one chamber to the one next above it and will finally escape through the vent at the top of the column. These air vents may be seen in Figure 30 as triangular holes at the top corner of the baffles which separate the mixing and settling chambers.

Figures 31, 32, and 33 are views of the multistage mixer-settler unit—Figure 31, a top view from an angle; Figure 32, a side view; Figure 33, a top view with the Teflon gasket in place. This unit is 44 in. long, 4 in. wide, and 2½ in. deep. It holds 6 liters and is designed for a total throughput of around 30 ml./min. The flow between stages is effected by gravity operating through the density difference of the two phases. A weir in each settling section controls the level of the heavy phase. The ratio of phases may be altered somewhat by changing the tilt of the mixer-settler.

Figure 34 shows the bank of stirrers for the mixer-settler. This bank fits over the Teflon gasket shown in Figure 33.

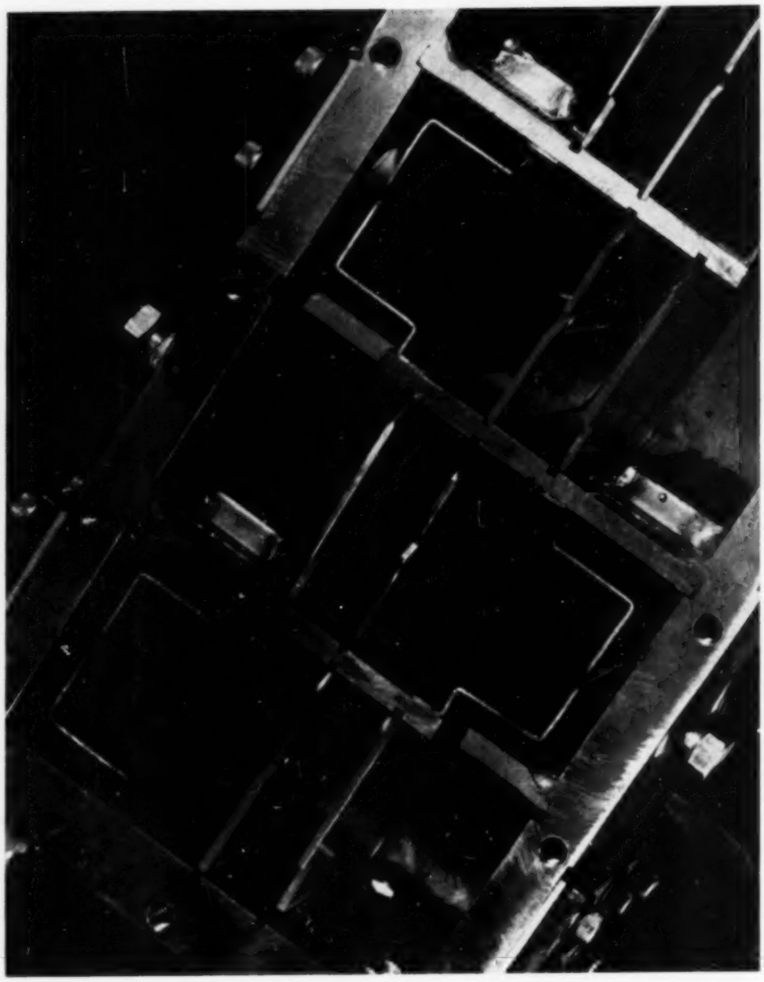


Fig. 29.

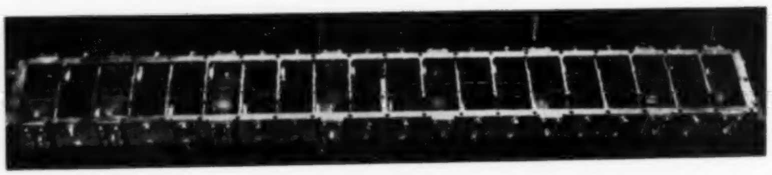


Fig. 31.

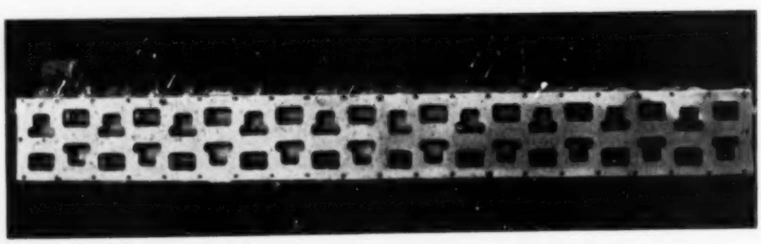


Fig. 33.

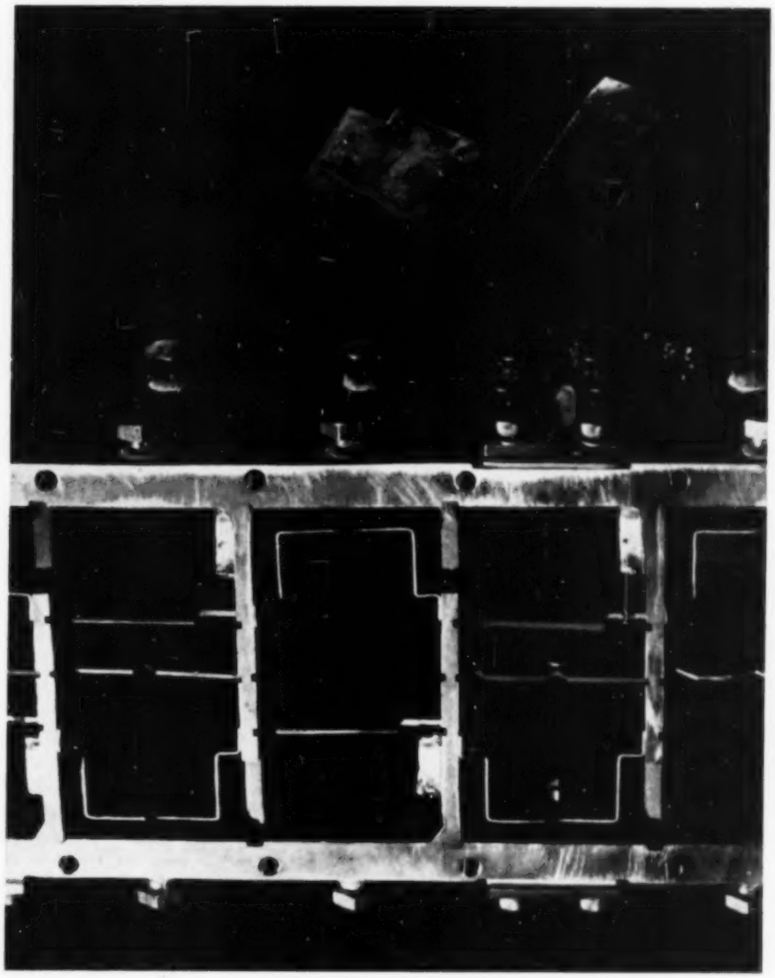


Fig. 30.

Fig. 32.

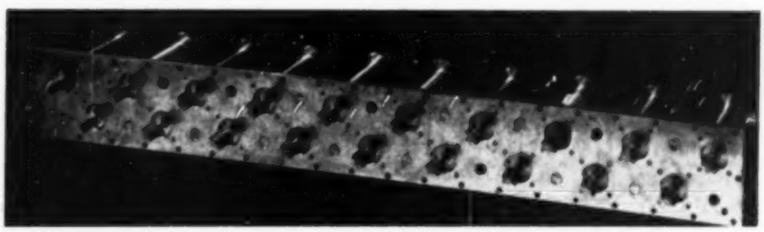


Fig. 34.

ACCESSORY EQUIPMENT

The only control apparatus needed for the mixer-settler is a means of controlling the take-off of the heavy phase. For this purpose a liquid-level controller which operated on the difference in conductivity between aqueous and organic phases is installed in the lowest chamber. It allows the light phase to overflow from the column as necessary.

The control circuit actuates a solenoid valve controlling the air supply to an air-operated valve in the heavy-phase discharge line. The control element is a platinum wire probe enclosed in glass tubing except for a tip about 1/4 in. long sealed into the unit by a compression fitting with Teflon packing.

The sampling tubing for the mixer is stainless steel. For each stage to be sampled two stainless steel sampling tubes of 0.025 in. I. D. tubing are provided, one opening near the bottom of the settler and the other ending near the top. This tubing is sealed in by individual compression fittings of Teflon. The discharge ends of these tubes are sharpened and are attached to a metal frame behind the shielding with each point supported about an inch from the end. Serum bottles with vacuum-tight stoppers are evacuated, and the sharpened point of the sampling tube is thrust through the stopper so that the vacuum pulls the fluid into the bottle.

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GAS FLOW

through small orifices

J. O. Osburn and Karl Kammermeyer State University of Iowa, Iowa City, Iowa

Measurements were made of the rate of flow of air and helium through small circular holes in thin plastic film. The results are shown as a graph of orifice coefficient vs. Reynolds number. The findings are similar to those previously reported for a square-edged orifice, and extend the range of orifice coefficient measurements to lower Reynolds numbers.

In the measuring of permeability of plastic membranes to gases (*1*), care was taken to exclude any samples of film which contained imperfections. Gas losses through such leaks were studied in the course of an investigation of gas flow through plastic films from balloons. Data taken on the rate at which gas loss took place have been correlated in terms of an orifice coefficient as a function of the Reynolds number. Reasonable agreement was found with the limited available information (*2*). Consequently, the range of values of Reynolds number has been extended in the direction of lower values.

The flow through a hole in a thin film may be correlated in terms of an orifice coefficient. A simplified form of the orifice equation should apply:

$$u = C\sqrt{2g\frac{\Delta P}{\rho}}, \qquad (1)$$

in which

u = gas velocity through the hole
C = orifice coefficient
g = acceleration due to gravity
ΔP = pressure drop across the film
ρ = gas density.

According to Drew and Genereaux (*2*), the orifice coefficient will be a function only of the Reynolds number and of the roughness. A graph of the coefficient vs. the Reynolds number for circular square-edged orifices with corner taps, given by these authors, cannot be applied to the case of holes in plastic films for three reasons. First, the lowest Reynolds number shown is 10, but lower values are encountered with low pressure drops across plastic films; second, the arrangement of pressure taps is not the same; and, finally, the effect of roughness is not known.

Experimental

The extruded polyethylene films used in the experiments ranged in thicknesses from 0.0005 in. to 0.04 in. (0.013 to 1.02 mm.), measured with a paper-thickness gauge. Small holes were punched with a sharp needle into samples of the film; for larger ones the film was held between two sheets of rigid plastic and the hole drilled with a drill press. The hole diameters had a range of 0.15 mm. to 1.20 mm. Measurements (with a low-power microscope with a built-in scale) were made on each hole both before and after testing, and no change was ever observed.

The apparatus consisted of a sample of film clamped in a ¾-in. pipe union. Into each end of the union were fixed rubber stoppers through which glass tees extended. The side-arm of each tee led to a manometer tap approximately 2 in. from the film. Gas from a cylinder or a compressed air line flowed into the apparatus through one tee and out through the other to the flow measuring device. The flow rates were such that there was negligible pressure drop in this distance. Moreover, it is clear from the dimensions that the permanent drop in pressure was measured.

For low pressure drops, from 0.07 to 0.70 in. (1.78 to 17.8 mm.) of water, a differential manometer containing dibutyl phthalate and ethylene glycol was used. For higher pressures a simple water manometer sufficed. The maximum pressure drop was 5.7 in. (145 mm.) of water. High rates of gas flow were measured with a rotameter calibrated, with the aid of a wet-test meter, for each gas used. With low flow rates, the gas was collected in a rubber balloon, and the volume measured in a gas burette. In the latter case the pressure in the gas-collecting balloon changed slightly during a

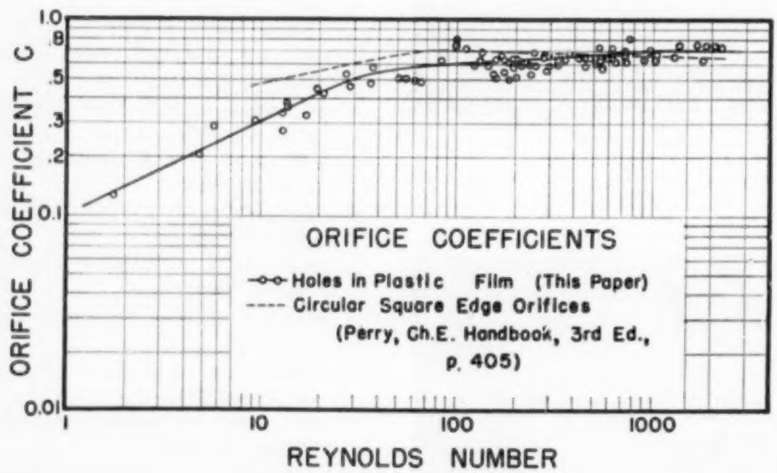

Fig. 1.

run; therefore the flow was adjusted manually to maintain a constant pressure drop.

Air and Grade A helium were used at room temperature, approximately 25° C. The air, filtered through glass wool, never moved at a velocity great enough to cause observable accumulation of dust particles in the orifice.

Results

Data obtained were the pressure drop and the rate of flow of gas, from which, with Equation (1), the orifice coefficient for each measurement was calculated. The Reynolds number was calculated, with gas density determined from the ideal gas law, and gas viscosity data obtained from the nomograph in the Chemical Engineers' Handbook (3). Figure 1 presents a graph of the data obtained, covering a range of Reynolds numbers from 1.8 to 2,200, with an average deviation from the curve of 8%. There is no trend of deviation with diameter, film thickness, or method of making the hole. For comparison, the curve for a square-edged circular orifice given by Drew and Genereaux (2) is dotted in. Although not corresponding exactly with the present data, it shows similar trends: the decreasing coefficient at low Reynolds numbers, and the approach to a constant value of about 0.65 at high Reynolds numbers.

An explanation of these trends is given by the work of Suran (4). In a publication on the porosity of electrovented plastics he derived an equation for the flow of air through holes in plastic films. The equation predicts that for small holes the flow, which he describes as frictional type, is proportional to the first power of the pressure drop. For large holes the flow is proportional to the square root of the pressure drop, as it is in simple orifice flow. Between the two extremes, which Suran found to be at hole diameters of 0.001 in. and 0.008 in. (0.025 to 0.203 mm.), there is a transition from one type of flow to the other.

To express the ratio of coefficients for two different pressure drops with correspondingly different velocities, other factors remaining constant, Equation (1) may be rearranged:

$$C = \frac{u}{\sqrt{2g\dfrac{\Delta P}{\rho}}}$$

so that

$$\frac{C_1}{C_2} = \frac{u_1}{\sqrt{2g\dfrac{\Delta P_1}{\rho}}}\,\frac{\sqrt{2g\dfrac{\Delta P_2}{\rho}}}{u_2} = \frac{u_1}{u_2}\sqrt{\frac{\Delta P_2}{\Delta P_1}} \qquad (2)$$

For small diameters the velocity is proportional to the first power of the pressure drop, so that

$$u = k_1 \Delta P \qquad (3)$$

Substituting Equation (3) in Equation (2), one obtains

$$\frac{C_1}{C_2} = \frac{k_1\Delta P_1}{k_1\Delta P_2}\sqrt{\frac{\Delta P_2}{\Delta P_1}} = \sqrt{\frac{\Delta P_1}{\Delta P_2}} \qquad (4)$$

Resubstituting by means of Equation (3) then gives

$$\frac{C_1}{C_2} = \sqrt{\frac{u_1}{u_2}} \qquad (5)$$

Evidently the coefficient is proportional to the square root of the velocity, or, since all terms except velocity in the Reynolds number are constant, to the square root of the Reynolds number. In Figure 1 the slope of the line in the region of low Reynolds number is approximately 0.5, which corresponds with the description in Equation (5). Although the diameter of the holes is greater than that given by Suran at the point at which transition begins, the deviation from frictional-type flow is not great.

For large diameters

$$u = k_2\sqrt{\Delta P}, \qquad (6)$$

so

$$\frac{C_1}{C_2} = \frac{k_2\sqrt{\Delta P_1}}{k_2\sqrt{\Delta P_2}}\sqrt{\frac{\Delta P_2}{\Delta P_1}} = 1 \qquad (7)$$

Therefore, in the region of high Reynolds numbers, the coefficients should reach a constant value, and the data plotted in Figure 1 show that they do.

The correlation shown in Figure 1 can be used in calculating the flow of gas through holes if the diameter and conditions of flow are known, or in estimating the diameter if the rate of flow is known.

Acknowledgment

The work reported herein was a part of a project sponsored by the Aeronautical Division of General Mills, Inc., under a contract with the Office of Naval Research. Thanks are expressed here for permission to publish this paper.

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ABSTRACTS

of papers published in "Heat Transfer—Research Studies for 1954."

No. 9, Vol. 50, of the Chemical Engineering Progress Symposium Series may be purchased from Chemical Engineering Progress, 120 East 41 Street, New York 17, N. Y., at $1.50 for members and $2.25 for nonmembers.*

Bed-Wall Heat Transfer in Fluidized Systems

Octave Levenspiel and J. S. Walton
Oregon State College

The effects of numerous variables on the heat-transfer coefficient between the container wall and the fluidized bed were determined for dense-phase gas-solid fluidized systems. A theory of heat transfer is proposed wherein the fact that the wall-bed heat-transfer coefficient in fluidized beds is higher than that in a gas-filled tube is explained by the diminution in thickness of the boundary layer at the tube wall.

Chem. Eng. Prog. Symposium Series, No. 9, **50**, 1 (1954).

Heat Transfer by Free Convection Through Liquids Between Two Horizontal Surfaces

Max Jakob and Pitam C. Gupta
Illinois Institute of Technology

This study deals with heat transfer by free convection through a layer of water or carbon tetrachloride bounded by a lower horizontal heating surface and an upper horizontal cooling surface. The losses from the heating plate have been evaluated by a combination of the finite differences and the relaxation methods. Deducting them from the total heat input gave results for the heat flow upward between surfaces at uniform temperatures.

Chem. Eng. Prog. Symposium Series, No. 9, **50**, 15 (1954).

Heat-Transfer Coefficients for Gases: Effect of Temperature Level and Radiation

H. J. Ramey, J. B. Henderson, and J. M. Smith
Purdue University

Convection heat-transfer coefficients for the cooling of steam and air flowing inside a 2-in. pipe were measured from 500 to 1,200° F. at gas-to-wall temperature differentials of 300 to 1,000° F. over a range of Reynolds numbers from 2,000 to 20,000 for air and 5,000 to 60,000 for steam. Data taken with different entrance conditions indicated that the convection coefficients could be increased several hundred per cent at constant Reynolds number by substituting a jet entry with well-developed turbulence for the usual straight-entrance section.

Chem. Eng. Prog. Symposium Series, No. 9, **50**, 21 (1954).

* See advertisement on page 76.

(Continued on page 200)

ABSTRACTS

Heat-Transfer Properties of Liquid-Solid Suspensions

Clyde Orr, Jr., and J. M. Dallavalle

Georgia Institute of Technology

Suspensions composed of a number of powdered solids in water or ethylene glycol have been investigated as heat-transfer media. The so-called Dittus-Boelter equation as modified by Sieder and Tate was found applicable to the transfer of heat between a suspension and a pipe wall. The conductivity of a suspension was found to be expressed by a relationship suggested by Maxwell for the analogous electrical situation, and suspension viscosity was described by an empirical expression.

Chem. Eng. Prog. Symposium Series, No. 9, **50**, 29 (1954).

Pressure Drop and Heat Transfer for Two-Phase, Two-Component Flow

Lawrence Fried

University of California

Pressure drop and heat transfer for an air-water mixture flowing in a horizontal 0.737-in. I.D. pipe were investigated at water rates of 2 to 26 gal./min. and air rates of 2 to 45 S.C.F.M., where the flow of both phases was always turbulent. When compensated for kinetic-energy changes, Martinelli's correlation for isothermal pressure drops is applicable to nonisothermal flow.

Chem. Eng. Prog. Symposium Series, No. 9, **50**, 47 (1954).

Some Problems in the Design of Light-Hydrocarbon Pyrolysis Coils

P. H. Calderbank

University of Toronto

In the sizing of a pyrolysis coil for ethane, propane, or butane feed stocks a formidable difficulty is the lack of agreement between equations proposed for the kinetics of the process. A method is therefore presented of arriving at the rate of reaction by calculating the amount of heat transferred to or from the reacting system from the external heat source or sink.

Chem. Eng. Prog. Symposium Series, No. 9, **50**, 53 (1954).

Critical Analysis of Metal Wetting and Gas Entrainment in Heat Transfer to Molten Metals

W. C. MacDonald and R. C. Quittenton

University of Toronto

Non-wetting of liquid metals on metal-transfer surfaces imposes a significant electrical resistance but an insignificant thermal resistance under nonboiling conditions, and a hypothesis of mechanical gas entrainment can account for the marked variations in heat-transfer results.

Chem. Eng. Prog. Symposium Series, No. 9, **50**, 59 (1954).

Statistical Methods

1. Introduction

The general purpose of this paper and the related one (*3*) is not to teach the use of these statistical methods but rather to inform the chemical engineer working on complex experiments of the existence of these methods which may be of potential benefit to him. This paper has the further specific purpose of offering the engineer a glimpse into some of the mathematical theory underlying the methods through the use of intuitive probability notions and some simple algebra. In an appendix (see page 205) intended for statistically more informed readers, general rules not elsewhere available are given for forming the needed mean squares, their numbers of degrees of freedom, and their expected values in balanced mixed model experiments; the exact distribution theory for the sums of squares is also given there for the case of normality.

2. Random Variables and Bowl Experiments

The treatment will be in terms of four basic concepts of statistical theory (*2*).

(i) A random variable y is a quantity which takes on different values $v_1, v_2, \ldots$ with respective probabilities $p_1, p_2, \ldots$. It may be simulated by drawings from a bowl of similar chips of which a proportion p_1 is marked v_1, a proportion p_2 marked v_2, etc., the contents of the bowl being thoroughly mixed before each drawing and the chip drawn being replaced after each drawing. In a long run of observations on the random variables or bowl drawings, the proportion of times the value v_1 is taken on will approach p_1, likewise for v_2 and p_2, etc.

(ii) The expected value of the random variable y, or its mean value, written $E(y)$ or μ_y, is defined to be

$$E(y) = \sum_i p_i v_i = \mu_y. \qquad (1)$$

In the bowl experiment this is the average value of the chips in the bowl. It is also the value approached in a sequence of drawings or observations if one keeps averaging all the values obtained since the beginning of the sequence.

(iii) The variance of y, written $\mathrm{Var}(y)$ or σ_y^2, is defined as

$$\mathrm{Var}(y) = \sum_i p_i(v_i - \mu_y)^2 = \sigma_y^2. \qquad (2)$$

The standard deviation σ_y has the same physical dimensions as the random variable y; the variance is a little easier to manipulate algebraically in the developments below (it does not matter much which we choose since if one is known the other is also). $\mathrm{Var}(y)$ is a measure of the fluctuation of the random variable about its mean or of the values of the chips in the bowl about their average value.

Expanding the middle member of (2) gives

$$\mathrm{Var}(y) = E(y^2) - [E(y)]^2.$$

In particular,

$$E(y^2) = \mathrm{Var}(y) \quad \text{if } E(y) = 0. \qquad (3)$$

The definitions (1) and (2) are appropriate for a random variable which can take on only discrete values; for a random variable taking on a continuum of values the sums in (1) and (2) are replaced by integrals. The above formula (3) and the formulas (4) and (5) below, all of which will be used extensively, are valid in either case. A bowl experiment always generates a discrete random variable but it can be made to approximate any continuous random variable sufficiently closely for all practical purposes.

(iv) The mathematical definition of the independence of two or more random variables requires more involved notation than is otherwise needed in this paper. The physical interpretation is that the values taken on by any one of the random variables are not influenced by the values taken on by the others. It will suffice for our present intuitive approach to say that if random variables correspond to bowl experiments with different bowls (one bowl for each variable) then they are independent.

3. Mean and Variance of Certain Functions of Random Variables

If y and z are random variables and a and b are constants then

$$E(ay + bz) = aE(y) + bE(z) \qquad (4)$$

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Professor Scheffé was formerly at Columbia University.

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for Evaluation of Several Sets of Constants and Several Sources of Variability

Henry Scheffé   University of California, Berkeley

If furthermore y and z are independent,

$$\mathrm{Var}(ay+bz) = a^2\mathrm{Var}(y) + b^2\mathrm{Var}(z) \quad (5)$$

These formulas are derived in elementary courses in probability or statistics. It is of interest that in the "analysis of variance" (the branch of statistical theory in which this subject falls) values of all the "expected mean squares" (the most important quantities that have to be computed) can be derived from the three elementary formulas (3), (4), and (5).

For any I quantities $y_1, y_2, \ldots, y_I$ their arithmetic average is denoted by the dot notation,

$$y\cdot = \sum_{i=1}^{I} y_i/I\,\cdot \quad (6)$$

If $y_1, y_2, \ldots, y_I$ are independent random variables with the same mean μ_y and the same variance σ_y^2 then from (4) and (5),

$$E(y\cdot) = \mu_y, \quad (7)$$

$$Var(y\cdot) = \sigma_y^2/I\,\cdot \quad (8)$$

The last is the well-known formula for the precision of the average of a set of measurements.

Since

$$y_1 - y\cdot = y_1 - \frac{1}{I}\sum_{1}^{I} y_i = \frac{I-1}{I}\,y_1 + \frac{1}{I}\sum_{2}^{I} y_i,$$

one obtains from (5)

$$Var(y_1 - y\cdot) = \left(\frac{I-1}{I}\right)^2\sigma_y^2 + \frac{1}{I^2}\sum_{2}^{I}\sigma_y^2 = \frac{I-1}{I}\,\sigma_y^2\,\cdot$$

From (4)

$$E(y_1 - y\cdot) = 0,$$

and hence from (3)

$$E(y_1 - y\cdot)^2 = Var(y_1 - y\cdot) = \frac{I-1}{I}\,\sigma_y^2\,\cdot$$

Similarly

$$E(y_i - y\cdot) = 0, \quad (9)$$

and

$$E(y_i - y\cdot)^2 = Var(y_i - y\cdot) = \frac{I-1}{I}\,\sigma_y^2, \quad (10)$$

and thus from (4),

$$E\left[\sum_{i=1}^{I}(y_i - y.)^2\right] = (I-1)\sigma_y^2. \quad (11)$$

The above sum of squares in square brackets is said to have $I-1$ degrees of freedom. Formula (11) is the reason the statistician divides the sum of squares by $I-1$ instead of I when he wants to estimate σ_y^2: The average of a sequence of such estimates of σ_y^2 would approach the true value of σ_y^2.

Later, when the interaction is assessed between two factors in a balanced experiment, it will be found that one must know the expected value of a sum of squares of the form

$$S = \sum_i\sum_k (z_{ik} - z_{i\,.} - z_{\cdot k} + z_{\,.\,.})^2 \quad (12)$$

where henceforth it is always understood that a summation on i runs from 1 to I, a summation on k from 1 to K, etc. When a subscript is replaced by a dot it indicates the average has been taken on that subscript; thus

$$z_{i\,.} = \sum_k z_{ik}/K,$$

$$z_{\,.\,.} = \sum_i\sum_k z_{ik}/(IK), \text{ etc.}$$

If the numbers z_{ik} are imagined arranged in a rectangular table with z_{ik} in the i-th row and k-th column, then the expression in parentheses in (12) is z_{ik} minus the averages of the row and column in which it appears plus the average of the whole table. If the z_{ik} in (12) are independent random variables with the same mean μ_z and the same variance σ_z^2, then the expected value is

$$E(S) = (I-1)(K-1)\sigma_z^2, \quad (13)$$

and S is said to have $(I-1)(K-1)$ degrees of freedom. The formula (13) is easily proved by writing

$$y_i^{(k)} = z_{ik} - z_{i\,.}\,, \quad (14)$$

so

$$y.^{(k)} = z_{\cdot k} - z_{\,.\,.}\,,$$

and

$$S = \sum_k S^{(k)}$$

where

$$S^{(k)} = \sum_i (y_i^{(k)} - y.^{(k)})^2. \quad (15)$$

From (9) and (10) applied to (14) with i, I, y_i replaced by k, K, z_{ik}, one gets $E(y_i^{(k)}) = 0$, $Var(y_i^{(k)}) = \sigma_z^2(K-1)/K$. Since the $y_i^{(k)}$ in (15) have equal means and equal variances we may apply (11) to (15) to find

$$E(S^{(k)}) = (I-1)\;Var\;(y_i^{(k)}) = \sigma_z^2(I-1)(K-1)/K.$$

Finally, by (4), $E(S) = \sum_k E(S^{(k)})$ and this gives (13).

4. Simplified Experiment of Vaurio and Daniel

To understand the extent to which it is possible in a balanced experiment to disentangle the different effects and assess them separately, and to understand the precisions with which this can be achieved are the main problems. Their solutions will be evident from the explicit mathematical formulas obtained. If this is understood for the simplified experiment it will be seen that exactly the same mathematical methods will work for the more complicated actual experiment, the added complication being largely of notation rather than of principles.

We depart from Vaurio and Daniel's description of the experiment in permitting an arbitrary number of levels for each factor, for example, an arbitrary number I of anneals, where they took $I = 2$, etc. Also their subscript l will be replaced by m. For each of the I anneals, J coils of tinplate are prepared with that anneal. Specimens are taken from the same K locations (head, tail, middle, etc.) on each of the IJ coils, M specimens, called "duplicates," from each location on each coil. From each specimen a tin can is made, packed with prunes, and the pack life of the can observed under standardized conditions. For further experimental details see (*3*). The observation, namely the observed pack life, obtained for the m-th duplicate at the k-th location on the j-th coil with the i-th anneal will be denoted by x_{ijkm}. The subscript i will always run from 1 to I, j from 1 to J, k from 1 to K, m from 1 to M.

The mathematical model is given by the equation

$$x_{ijkm} = \mu + \alpha_i^A + a_{ij}^C + \alpha_k^L + \alpha_{ik}^{AL} + a_{ijk}^{CL} + a_{ijkm}^D . \tag{16}$$

All that is necessary to know about μ is that it is an additive constant (it may be interpreted as the true grand average pack life of coils, averaged over the I anneals and K locations). The sources of the other terms are shown in Table 1. The α symbols denote constants, or Model I effects, the a symbols denote random variables, or Model II effects. It is very important to understand how the decision is made for each effect—to treat it as Model I or Model II. The Model II effects are regarded as though they were drawn from a bowl or "population" of effects for which interest here is only in certain statistical or average properties characterizing the bowl and not specifically in the particular individuals who happened to be drawn. Consider, for example, the anneal effects: Is one really interested in (*i*) the effects on average pack life of each of the particular I anneals used in the experiment, or only in (*ii*) the variation of anneals in a "bowl" of possible anneals from which the experimental anneals may be imagined drawn? It is clear that there is interest in (*i*) for the anneals and so they are treated as a Model I factor. If the same question is asked about the coils, locations, and duplicates, one is led to classify these as Model II, I, and II respectively. The interactions, such as anneal $\times$ location, represent differential effects of one of the factors caused by different levels of the other (or others). In deciding about the interactions among a given set of factors, the interaction effect is treated as Model I if all the factors involved in the interaction are Model I, otherwise it is treated as Model II.

In considering whether further terms for other interactions should be added to the model in Equation (16), they may be ruled out in two possible ways: First, the design of the experiment may not permit their evaluations; for example, if an $A \times C$ interaction term is considered, it would have to be a_{ij}^{AC} and this would combine in (16) with the term a_{ij}^C so that only the sum appears and the two effects would be impossible to disentangle (this interaction is "confounded" with the coil effect). Second, there may be a willingness to assume an interaction nonexistent or practically negligible from physical considerations; for example, one is willing to assume that there is no $A \times D$ interaction because past experience has indicated that variation among duplicates is not affected by different anneals. (The statistician usually calls the last term in (*16*) the "error term" and rules out all interactions with "error.")

All the random variables in Equation (16) are assumed *independent*. It may be assumed that

$$\alpha_{.}^A = 0, \tag{17}$$

because, if this were not so, $\alpha_i^A - \alpha_{.}^A$ could be taken as new α_i^A and $\mu + \alpha_{.}^A$ as new μ, and the new α_i^A would then satisfy (17). Similarly the conditions

$$\alpha_{.}^L = 0, \tag{18}$$

and

$$\alpha_{i.}^{AL} = 0,\ \alpha_{.k}^{AL} = 0 \tag{19}$$

may be justified by writing

$$\mu + \alpha_i^A + \alpha_k^L + \alpha_{ik}^{AL} = (\mu + \alpha_{.}^A + \alpha_{.}^L + \alpha_{..}^{AL}) + (\alpha_i^A - \alpha_{.}^A + \alpha_{i.}^{AL} - \alpha_{..}^{AL}) + (\alpha_k^L - \alpha_{.}^L + \alpha_{.k}^{AL} - \alpha_{..}^{AL}) + (\alpha_{ik}^{AL} - \alpha_{i.}^{AL} - \alpha_{.k}^{AL} + \alpha_{..}^{AL}),$$

taking the four expressions in parentheses on the right side of the equation as new μ, α_i^A, α_k^L, α_{ik}^{AL}, and noting that they will then satisfy (17), (18), (19). It is important to see that similar conditions cannot be assumed on the a symbols: If a certain average of Model II effects were forced to be zero this would violate their desired independence.

About the Model II effects: It is assumed that the IJ coil effects a_{ij}^C behave like observations on the same random variable or like drawings (with replacement) from the same bowl. The variance of this random variable will be denoted by σ_C^2. Its expected value is a constant which may be assumed to be zero, since, if it were not zero, it could be absorbed into the constant μ. Similarly the IJK Model II interaction effects a_{ijk}^{CL} will be assumed to have a common variance σ_{CL}^2 and expected value zero, and the $IJKM$ "duplicate" effects a_{ijkm}^D will be assumed to have a common variance σ_D^2 and expected value zero. The three variances σ_C^2, σ_{CL}^2, σ_D^2 characterizing the Model II effects, as well as all the α's characterizing the Model I effects, and also μ, are regarded as unknown constants (or "parameters"). In the title of this paper the "constants," are the α's, the "sources of variability" are characterized by the σ^2's.

The following six kinds of averages of the observations x_{ijkm} are of interest: For convenience Equation (16) for x_{ijkm} is again written:

Table 1.—Notation

Source	Abbreviation (superscript)	Level (subscript)	Effect	SS	MS = (SS)/(df)
Anneals	A	i	α_i^A	$(SS)^A$	$(MS)^A$
Coils	C	j	a_{ij}^C	$(SS)^C$	$(MS)^C$
Locations	L	k	α_k^L	$(SS)^L$	$(MS)^L$
Duplicates	D	m	a_{ijkm}^D	$(SS)^D$	$(MS)^D$
Anneal $\times$ location	AL		α_{ik}^{AL}	$(SS)^{AL}$	$(MS)^{AL}$
Coil $\times$ location	CL		a_{ijk}^{CL}	$(SS)^{CL}$	$(MS)^{CL}$

$$x_{ijkm} = \mu + \alpha_i^A + \mathrm{a}_{ij}^C + \alpha_k^L + \alpha_{ik}^{AL} + \mathrm{a}_{ijk}^{CL} + \mathrm{a}_{ijkm}^D, \tag{16}$$

$$x_{ijk\cdot} = \mu + \alpha_i^A + \mathrm{a}_{ij}^C + \alpha_k^L + \alpha_{ik}^{AL} + \mathrm{a}_{ijk}^{CL} + \mathrm{a}_{ijk\cdot}^D, \tag{20}$$

$$x_{ij\cdot\cdot} = \mu + \alpha_i^A + \mathrm{a}_{ij}^C + 0 + 0 + \mathrm{a}_{ij\cdot}^{CL} + \mathrm{a}_{ij\cdot\cdot}^D, \tag{21}$$

$$x_{i\cdot\cdot\cdot} = \mu + \alpha_i^A + \mathrm{a}_{i\cdot}^C + 0 + 0 + \mathrm{a}_{i\cdot\cdot}^{CL} + \mathrm{a}_{i\cdot\cdot\cdot}^D, \tag{22}$$

$$x_{\cdot\cdot\cdot\cdot} = \mu + 0 + \mathrm{a}_{\cdot\cdot}^C + 0 + 0 + \mathrm{a}_{\cdot\cdot\cdot}^{CL} + \mathrm{a}_{\cdot\cdot\cdot\cdot}^D, \tag{23}$$

$$x_{i\cdot k\cdot} = \mu + \alpha_i^A + \mathrm{a}_{i\cdot}^C + \alpha_k^L + \alpha_{ik}^{AL} + \mathrm{a}_{i\cdot k}^{CL} + \mathrm{a}_{i\cdot k\cdot}^D, \tag{24}$$

$$x_{\cdot\cdot k\cdot} = \mu + 0 + \mathrm{a}_{\cdot\cdot}^C + \alpha_k^L + 0 + \mathrm{a}_{\cdot\cdot k}^{CL} + \mathrm{a}_{\cdot\cdot k\cdot}^D, \tag{25}$$

Each of these equations is formed from the preceding one by taking the average indicated by the new dot, except for (24) which is obtained from (20). These equations indicate to what extent an estimate of a certain effect is influenced by the other effects. For example, an estimate of the (true) grand average pack life for the i-th anneal is the observed average for the i-th anneal, namely $x_{i\cdot\cdot\cdot}$ in Equation (22). This is seen to be completely free of the location effects α_k^L and the anneal $\times$ location interactions α_{ik}^{AL}. It is contaminated to some extent by the coil effects a_{ij}^C for the J coils on the i-th anneal, the coil $\times$ location interactions a_{ijk}^{CL} and the duplicate effects a_{ijkm}^D, but to a much less extent than the original measurements: Thus, $\mathrm{a}_{i\cdot}^C$ being an average of J independent random variables a_{ij}^C with the same variance σ_C^2 has a variance only $1/J$ as large, σ_C^2/J, by (8). Similarly, the contaminating effect, as measured by the variance, due to the coil $\times$ location interaction is only $1/(JK)$ as large as in the original observations, that of the duplicates only $1/(JKM)$ as large. This situation is quite general in balanced experiments: the undesired Model I effects drop out completely from the estimates, the undesired Model II effects contaminate the estimates to a lesser extent than the original measurements.

5. Construction of Analysis of Variance Table and Derivation of E(MS)'s.

What conclusions are desired about the unknown effects? In general, interest is centered in the individual values of the Model I effects, but only in the scatter of the Model II effects as measured by their variances. The statistician has two kinds of tools to assist: first, the method of significance tests to decide whether certain effects are present or absent, and second, a method of estimation for calculating intervals ("confidence intervals") from the data, within which one can be quite confident the unknown quantities lie. For either method it is convenient to construct an analysis of variance table as shown in Table 2.

Before trying to motivate and explain this table, let us list for later reference the definitions of some new symbols appearing there in the last column:

$$\sigma_A'^2 = \sum_i (\alpha_i^A)^2/(I-1), \tag{26}$$

$$\sigma_L'^2 = \sum_k (\alpha_k^L)^2/(K-1), \tag{27}$$

$$\sigma_{AL}'^2 = \sum_i \sum_k (\alpha_{ik}^{AL})^2/[(I-1)(K-1)]. \tag{28}$$

These quantities are written as σ'^2 instead of σ^2 as a reminder that they are not the variances of any random variables but the mean squares of certain sets of Model I effects: The divisor is $I-1$ in (26) instead of I only because this simplifies the notation in the last column of Table 2; similarly for the other divisors.

The first line of the table will now be explained. It will be recalled that $x_{i\cdot\cdot\cdot}$ is an estimate of $\mu + \alpha_i^A$, the true grand average pack life for the i-th anneal. From Formula (22)

$$x_{i\cdot\cdot\cdot} = \mu + \alpha_i^A + \mathrm{a}_{i\cdot}^C + \mathrm{a}_{i\cdot\cdot}^{CL} + \mathrm{a}_{i\cdot\cdot\cdot}^D$$

the expected value and variance of the estimate can be calculated. The expected value of each of the last three terms above is zero by (7), so by (4),

$$E(x_{i\cdot\cdot\cdot}) = \mu + \alpha_i^A. \tag{29}$$

By (5),

$$\mathrm{Var}(x_{i\cdot\cdot\cdot}) = \mathrm{Var}(\mathrm{a}_{i\cdot}^C) + \mathrm{Var}(\mathrm{a}_{i\cdot\cdot}^{CL}) + \mathrm{Var}(\mathrm{a}_{i\cdot\cdot\cdot}^D),$$

and applying (9) to each of the three terms on the right, one finds

$$\mathrm{Var}(x_{i\cdot\cdot\cdot}) = \sigma_C^2/J + \sigma_{CL}^2/(JK) + \sigma_D^2/(JKM). \tag{30}$$

A measure of how much these estimates for the different anneals differ from each other as a group is

$$S_A = \sum_i (x_{i\cdot\cdot\cdot} - x_{\cdot\cdot\cdot\cdot})^2, \tag{31}$$

which is the same as $(SS)^A$, the "sum of squares due to anneals," in Table 2, except for a numerical factor.* In order to calculate $E(S_A)$ easily, write

$$y_i = x_{i\cdot\cdot\cdot} - \alpha_i^A,$$

so that the y_i are independent with a common mean μ and common variance

$$\mathrm{Var}(y_i) = \mathrm{Var}(x_{i\cdot\cdot\cdot}) \tag{32}$$

given by (30). Substituting

$$x_{i\cdot\cdot\cdot} = y_i + \alpha_i^A, \quad x_{\cdot\cdot\cdot\cdot} = y_\cdot$$

in (31), one obtains

$$S_A = \sum_i (\alpha_i^A + y_i - y_\cdot)^2$$

$$= \sum_i (\alpha_i^A)^2 + \sum_i (y_i - y_\cdot)^2 + 2\sum_i \alpha_i^A (y_i - y_\cdot)$$

and hence

$$E(S_A) = \sum_i (\alpha_i^A)^2 + (I-1)\ \mathrm{Var}(y_i) + 0, \tag{33}$$

the middle term on the right coming from (11), the last from (9). Since

$$(MS)^A = (SS)^A/(I-1) = [JKM/(I-1)]S_A,$$

therefore

$$E[(MS)^A] = [JKM/(I-1)]E(S_A), \tag{34}$$

and substituting into (34) successively from (33), (32), (30), and (26), one finally gets the expression for $E[(MS)^A]$ given in the last column of the table.

To build $(MS)^C$, which is to measure the scatter of the coil effects, one starts with the coil average $x_{ij\cdot\cdot}$ of the measurements on the j-th coil with the i-th anneal. From Equation (21) one sees that for the J coils with the i-th anneal the $x_{ij\cdot\cdot}$ all have the same expected value $\mu + \alpha_i^A$ and the same variance

$$\mathrm{Var}(x_{ij\cdot\cdot}) = \sigma_C^2 + \sigma_{CL}^2/K + \sigma_D^2/(KM), \tag{35}$$

and hence taking the sum of squares about the average for the coils with the i-th anneal, one gets from (11)

$$E\left[\sum_j (x_{ij\cdot\cdot} - x_{i\cdot\cdot\cdot})^2\right] = (J-1)\ \mathrm{Var}(x_{ij\cdot\cdot}). \tag{36}$$

If we now sum on i, from (36) and (35) the $E[(MS)^C]$ given in the table can now be easily found. This is seen to depend not only on the scatter

* These numerical factors are chosen to make the coefficient of σ_D^2 in the last column unity.

of the coil effects but also on that of the other Model II effects.

The reader should now have no difficulty in similarly handling the next two lines of the table. It will next be indicated how the interaction SS are treated: To measure the $A \times L$ interaction one would like to combine the averages in equations (22) to (25) in such a way that the term a_{ik}^{AL} is present and the others are suppressed. This may be achieved by combining Equations (22), (23), (24), (25) with signs $-, +, +, -$, respectively: The first four terms on the right side of the model Equation (16) then drop out entirely and we are left with the desired a_{ik}^{AL} plus certain averages of the last two terms in (16). The result may be written:

$$x_{i\,.\,k\,.} - x_{i\,.\,.\,.} - x_{.\,.\,k\,.} + x_{.\,.\,.\,.} = a_{ik}^{AL} + y_{ik}, \tag{37}$$

where the y_{ik} is of the form

$$y_{ik} = z_{ik} - z_{i\,.} - z_{.\,k} + z_{.\,.}$$

with

$$z_{ik} = a_{i\cdot k}^{CL} + a_{i\cdot k\cdot}^{D}$$

It should be noted that

$$E(z_{ik}) = 0, \quad E(y_{ik}) = 0,$$

and

$$\mathrm{Var}(z_{ik}) = \sigma_{CL}^2/J + \sigma_D^2/(JM). \tag{38}$$

Squaring and summing (37) on i and k, and denoting by S_{AL} the sum of squares

$$S_{AL} = \sum_i \sum_k (x_{i\,.\,k\,.} - x_{i\,.\,.\,.} - x_{.\,.\,k\,.} + x_{.\,.\,.\,.})^2,$$

one gets

$$S_{AL} = \sum_i \sum_k (a_{ik}^{AL} + y_{ik})^2$$

$$= \sum_i \sum_k (a_{ik}^{AL})^2 + \sum_i \sum_k y_{ik}^2$$

$$+ 2 \sum_i \sum_k a_{ik}^{AL} y_{ik}$$

Taking expected values, one has

$$E(S_{AL}) = \sum_i \sum_k (a_{ik}^{AL})^2 +$$

$$E\Big[\sum_i \sum_k (z_{ik} - z_{i\,.} - z_{.\,k} + z_{.\,.})^2\Big]$$

$$+ 0.$$

The expected value on the right is seen to be that of a sum of squares of the form (12), so it can be evaluated by the Formula (13), with the result

$$E(S_{AL}) = \sum_i \sum_k (a_{ik}^{AL})^2$$

$$+ (I-1)(K-1)\ \mathrm{Var}(z_{ik}). \tag{39}$$

Substituting (38) into (39) and using

$$(MS)^{AL} = \{JM/[(I-1)(K-1)]\}\, S_{AL},$$

one finds the expression for $E[(MS)^{AL}]$ given in the table. The derivation for $[E(MS)^{CL}]$ is similar and easier.

6. Uses of Analysis of Variance Table.

In constructing the analysis of variance table for numerical calculation from the data a mean square column is added, where for each line $MS = (SS)/(df)$. Once Table 2 has been constructed it is easy† to see from the $E(MS)$ column which is the appropriate significance test for each kind of effect. For example, there is no difference due to anneals if and only if $\sigma_A'^2 = 0$. The last column of the table tells that the significance of anneals is to be determined by comparing $(MS)^A$ with $(MS)^C$: These mean squares have the same expected value if and only if $\sigma_A'^2 = 0$, regardless of the values of other unknown quantities ($\sigma_L'^2$, $\sigma_{AL}'^2$, σ_C^2, σ_{CL}^2, σ_D^2). If the ratio $(MS)^A/(MS)^C$ is "too large" the conclusion is drawn that there are real differences in pack life due to anneals: What is "too large" is given by tables for the "F-distribution" with $(I-1)$ and $I(J-1)$ degrees of freedom.‡ The table shows at once that $(MS)^C$, $(MS)^L$, and $(MS)^{AL}$ are to be compared with $(MS)^{CL}$, and that $(MS)^{CL}$ is to be compared with $(MS)^D$, to test the significance of the various effects.

The analysis of variance table is useful also for estimation by confidence intervals. Suppose, for example, it were desired to estimate the difference between two anneals, say $a_1^A - a_2^A$. A "point estimate" would be $x_{1\,.\,.\,.} - x_{2\,.\,.\,.}$. In order to calculate an h to make an interval $x_{1\,.\,.\,.} - x_{2\,.\,.\,.} \pm h$ within which one is 95% confident that the

† It is not always so easy. In more complicated cases where one wishes to test whether some $\sigma_s^2 = 0$ (or $\sigma_s'^2 = 0$) and $E[(MS)^r] = C\sigma_s^2 + Q$, where C is a known constant, there may not be any $(MS)^v$ in the table for which $E[(MS)^v] = Q$. More complicated approximate tests then have to be used.

‡ This requires the additional assumption that all the a's (Model II effects) have normal distributions.

Table 2.—Analysis of Variance Table

SS	Formula	df	E(MS)
$(SS)^A$	$J\ K\ M \sum_i (x_{i\,.\,.\,.} - x_{.\,.\,.\,.})^2$	$I-1$	$JKM\sigma_A'^2 + KM\sigma_C^2 + M\sigma_{CL}^2 + \sigma_D^2$
$(SS)^C$	$K\ M \sum_i \sum_j (x_{ij\,.\,.} - x_{i\,.\,.\,.})^2$	$I(J-1)$	$KM\sigma_C^2 + M\sigma_{CL}^2 + \sigma_D^2$
$(SS)^L$	$I\ J\ M \sum_k (x_{.\,.\,k\,.} - x_{.\,.\,.\,.})^2$	$K-1$	$IJM\sigma_L'^2 + M\sigma_{CL}^2 + \sigma_D^2$
$(SS)^D$	$\sum_i \sum_j \sum_k \sum_m (x_{ijkm} - x_{ijk\,.})^2$	$IJK(M-1)$	σ_D^2
$(SS)^{AL}$	$J\ M \sum_i \sum_k (x_{i\,.\,k\,.} - x_{i\,.\,.\,.} - x_{.\,.\,k\,.} + x_{.\,.\,.\,.})^2$	$(I-1)(K-1)$	$JM\sigma_{AL}'^2 + M\sigma_{CL}^2 + \sigma_D^2$
$(SS)^{CL}$	$M \sum_i \sum_j \sum_k (x_{ijk\,.} - x_{i\,.\,k\,.} - x_{ij\,.\,.} + x_{i\,.\,.\,.})^2$	$I(J-1)(K-1)$	$M\sigma_{CL}^2 + \sigma_D^2$

true difference $a_1^A - a_2^A$ lies, the variance of x_i . . . would have to be considered; this is given by Equation (30). Now the three σ^2's on the right of (30) are unknown but it is seen immediately from the last column of the table that an estimate of the right side of (30) is obtained by dividing $(MS)^C$ by JKM, and this estimate is used in the calculation of the half-width h of the confidence interval.

The $E(MS)$ column of the table may be similarly used for getting confidence intervals for all the Model I effects. It leads also to estimates of the σ's that measure the Model II effects: For example a "point estimate" of σ_C^2 (which measures the scatter of the coil effects) is $(MS)^C - (MS)^{CL}$ divided by KM. The table would be useful also in constructing interval estimates of these σ^2's but this is too complicated to treat here, as is also the derivation of general rules for construction of the various SS, their df, and $E(MS)$ in the general case of a mixed model balanced experiment; however, these rules will be indicated in the accompanying appendix for the benefit of statistically more advanced readers; the principles leading to these rules are the same as above. In conclusion, it should be stated that in a mixed model experiment one cannot speak of "the" precision of the experiment: there are different precisions for the different kinds of effects, and the $E(MS)$ column of the table is valuable for calculating these.

APPENDIX: GENERAL RULES FOR CALCULATING SS, *df*, AND *E*(*MS*)

This appendix should be intelligible to the reader who has had experience in calculating interaction sums of squares in some simple analyses of variance. In order to apply these general rules (1) for balanced mixed model experiments it is necessary to write out fully the model equation similar to (16) which is appropriate to the experiment being considered.

One needs to refer to the usual rules for writing the various sums of squares in the simplest cases where there is no "nesting" in the design (in the above example coils are nested within anneals). For a main effect sum of squares where the level of the factor is indexed by the subscript i, the standard expression for the SS is, (except for a constant multiplier)

$$\sum_i (z_i - z_.)^2, \tag{40}$$

where z_i denotes the average of all observations at the i-th level of the factor. For a two-factor interaction, where the factors are indexed by i and k, the standard expression for the SS is given by (12), where z_{ik} denotes the average of all observations for which the first factor is at the i-th and the second at the k-th level. Similarly for a three-factor interaction where the factors are indexed by i, k, m, the standard SS is

$$\sum_i \sum_k \sum_m (z_{ikm} - z_{ik.} - z_{i.m} - z_{.km} + z_{i..} + z_{.k.} + z_{..m} - z_{...})^2, \tag{41}$$

etc.

To write the SS for the main effects of any factor or the SS for the interaction of any set of factors, find the term in the model equation that has this factor or set of factors as its superscripts; this will be called the "key term" (if no such term is present there is no corresponding SS to calculate). The subscripts that index the factor or factors involved will be called the "live subscripts"; they will be present among the subscripts of the key term. There may also be other subscripts on the key term in the case of nesting; these (if any) will be called the "dead subscripts." All subscripts on x on the left side of the model equation not present on the key term will be called "absent subscripts." The corresponding capital letters, showing the range of the subscripts, will be called the "live," "dead," and "absent limits" respectively. To illustrate the terminology, suppose the three factors A, B, C are respectively indexed by i, j, k and we want the SS for the AxBxC interaction. Then the live subscripts are i, j, k, and the live limits are I, J, K. The live subscripts i, j, k appear on the key term, which is the term in the model equation with superscripts ABC. Suppose the key term has also the subscripts m and p; these are then the dead subscripts. If the subscripts on x are $i\ j\ k\ m\ n\ p\ q\ r$, then the absent limits are N, Q, R.

We now form the standard expression like (40), (12), (41), etc., where the summations are on the live subscripts, the first z term inside the parentheses is replaced by x with the subscripts on x such that the absent subscripts are replaced by dots. The dead subscripts appear on every term inside the parentheses in the standard expression, which is now summed on the dead subscripts, and finally multiplied by the product of all the absent limits; the result is the desired SS. In the example just used, since the live subscripts are i, j, k, the standard expression is (41) with i, k, m replaced by i, j, k. The role of z_{ijk} is played by $x_{ijkm.p..}$, hence that of $z_{ij.}$ by $x_{ij.m.p..}$, etc., giving as the standard expression

$$\sum_i \sum_j \sum_k (x_{ijkm.p..} - x_{ij.m.p..} - x_{i.km.p..} - x_{.jkm.p..} + x_{i..m.p..} + x_{.j.m.p..} + x_{..km.p..} - x_{...m.p..})^2.$$

If this expression is now summed on the dead subscripts m, p, and multiplied by the product of the absent limits NQR, we have $(SS)^{ABC}$.

The last rule above for the coefficient of the summation as a product of absent limits holds also for the corresponding σ^2's or σ'^2's wherever they appear in the $E(MS)$ column. If in the above example the key term is a_{ijkmp}^{ABC}, the corresponding σ^2 is σ^2_{ABC}, if the key term is a_{ijkmp}^{ABC}, the corresponding σ'^2 is σ'^2_{ABC}, in either case wherever this σ^2 or σ'^2 appears in the $E(MS)$ column its coefficient will be NQR. Each $E(MS)$ is a sum of σ^2's or σ'^2's with these coefficients, and it remains only to state which are present. The one corresponding to the SS whose $E(MS)$ is being calculated is always present; thus $E(MS)^{ABC}$ has present σ^2_{ABC} or σ'^2_{ABC}. Which others are present may be determined as follows: Consider the subscripts on the key term corresponding to the SS in question. Also present will be the σ^2's corresponding to all a terms (*nothing* for any a term) whose subscripts include all the subscripts on the key term. Continuing the example, if there is an a term with subscripts $i\ j\ k\ m\ n\ p\ q$, we must include the σ^2 corresponding to this term (the factors in the subscript of this σ^2 are those in the superscript of this a term). We would ignore an a term with subscripts $i\ j\ m\ n\ p\ q$ or an a term with subscripts $i\ j\ k\ m\ n\ p\ q$.

The rule for the number of df for the SS is that it is the product of the dead limits for the key term corresponding to the SS (interpreted as unity if there are none) by the product of one less than each of the live limits. Thus, to conclude the example, $df = MP(I-1)(J-1)(K-1)$.

Should the reader attempt to apply these rules to another experiment, he is urged first to test his correct use of them by constructing Table 2 from the model equation (16).

In this last paragraph we shall address ourselves only to the reader with some knowledge of the sampling theory of normal populations. Making use of the rules developed in this paper, it is possible to state simply the exact distribution of all the SS in the table, provided we add the assumption that every Model II effect is normally distributed: In the case of a balanced experiment the various SS are statistically independent and each is distributed as a constant times a noncentral chi-square. (A noncentral chi-square variable with f degrees of freedom and noncentrality parameter δ^2 is distributed like the sum of the squares of f independent normal variables each with unit variance and with the sums of squares of their f means equal to δ^2. If $\delta^2 = 0$ the noncentral chi-square is an ordinary or central chi-square.) In the expression for the $E(MS)$ of the SS there may or may not be a term present which is a multiple of a σ'^2; if there is, call this term θ', if there is not, define $\theta' = 0$. Let θ be the remaining part of the expression for the $E(MS)$, so $E(MS) = \theta' + \theta$. Let f now denote the number of df of the SS. Then the SS is distributed as θ times a noncentral chi-square with f degrees of freedom and noncentrality parameter $\delta^2 = f\theta'/\theta$.

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ENGINEERS CAN WRITE BETTER

The Long and Short of It

H. J. Tichy   Hunter College of the City of New York

Part II

"Must every sentence be short?" asks Peter Pilot, B.Ch.E. '36. "Everyone tells me to write short sentences, but take this process for example. The name of it is five words alone, and what I have to write about it is complicated. How can all my sentences be short?"

No other advice has been pressed upon chemical engineers with such relentless determination as has the necessity for short sentences. Because engineering articles, like other technical writing, are not the easiest reading, the attack on the writing of engineers has been particularly vigorous. The sentences in newspaper and magazine articles on science are just as long and sometimes longer than the sentences in the writing of chemical engineers; yet engineers are constantly told, "Use short sentences."

One adviser comments on a forty-three-word sentence in a technical article, "If this sentence is read aloud the reader will be out of breath by the time he reaches the end." An article on letter writing advises, "Avoid use of long sentences," and mentions no exceptions although it allows exceptions to other rules. A speaker at a convention summarizes, "We have been hearing much from the readability experts about the need to write simply. They say, 'Use short words and sentences.'"

The Literature

In his own field the chemical engineer approaches a problem by examining the literature. When Peter Pilot turns to authorities on writing, he does not find standard handbooks favoring any single kind of sentence. One authority writes, ". . . any kind of sentence becomes bad if used so frequently that it bores the reader. Avoid a series of short, simple sentences. Vary the length." (*1*) "Sentences should be varied in length and structure as a means of obtaining specific effects," advises one of the latest handbooks on writing. "Anyone who has glanced at a reader used in the primary grades knows that a page made up almost entirely of short, simple sentences can be extremely monotonous." (*2*) "Variety in sentence length—change of pace—helps sustain interest," states another handbook. "In this respect, language is again like music: an absolutely even tempo makes a piece seem wooden." (*3*) These are truisms about writing. How does it happen that the advice given chemical engineers is so different?

Pneumatic Testing

Those who urge on chemical engineers the short sentence and the short word are seldom writers or teachers of writing; they are specialists in other fields. Their advice about writing, their interpretation and misinterpretation of readability studies, and their emphasis on a cure-all demonstrate the dangers of half knowledge. When a short-sentence admirer complains that reading a forty-three-word sentence aloud leaves him out of breath, one ponders with amusement the extremes of pneumatic testing. The idea that a sentence must be read in one breath was buried long ago in a family grave next to the idea that a comma always represents a short pause, a semicolon a longer pause, and a period a full stop. One wonders whether even a trained singer can read aloud in one breath the eighty-two word sentence in the *Gettysburg Address*. One imagines a breathless husband and wife reading to each other over the breakfast table the fifty- to seventy-word sentences in the morning newspaper. Surely the ensuing panting leads to choking over toast and coffee. And what of the Elizabethans, who wrote even longer sentences? Were they longer-winded?

Short-sentence addicts often urge the engineer to read the classics to improve his style. How do they explain to him the exceedingly long sentences he finds in the classics and even in the least likely modern fiction? In one Hemingway story a textbook writer found sentences averaging eight and one-half words in length and in another Hemingway story in the same volume, forty-nine (*4*). The chemical engineer, ignorant as a babe of the rhetorical principles involved, may well conclude that *no* particular sentence length is correct or that *any* length is correct. Fortunate indeed for writing that "out of the mouths of babes. . . ."

Fit to Print

The chemical engineer writes his reports and technical papers for a special group of readers—fellow engineers, engineering students, intelligent laymen. As they roughly approximate in intelligence the readers of a paper like *The New York Times*, a comparison of the lengths of sentences in engineering articles with the lengths of sentences in *Times* stories on subjects of comparable difficulty is fair. Three science stories chosen from one issue of the *Times* (Figures 1 to 3) treat work on an antibiotic as a weapon against cancer, the impairment of protein food by heat, and harnessing the energy of the sun as a source of industrial power. The word lengths of sentences in these stories follow:

Times article A 58, 6, 27, 45, 18, 24, 37, 23, 45, 13, 46, 21, 28, 29, 40, 26, 7, 33, 14, 25, 70, 17, 24

Average—30 for first fifteen sentences

Times article B 30, 55, 22, 22, 49, 8, 39, 21, 22, 29, 32, 31, 12, 42

Average—29

Times article C 25, 31, 19, 49, 14, 47, 15, 14, 32, 21, 39, 40, 29, 31, 22, 34, 24, 49, 25, 46, 20, 42, 26, 64, 6

Average—28 for first fifteen sentences

For comparison, articles from recent issues of C.E.P. and the Symposium Series were selected at random, one a study of filter cakes, the other an article on heat transfer. The engineering articles, which are not popular treatments, are much longer than the newspaper stories; therefore the beginning, including the abstract and part of the experiment, of one article (C.E.P.A), the ending of the same article (C.E.P.B), and the beginning of a study in the Symposium Series (S.S.) were chosen (Figures 4 to 6). The sentence lengths follow:

C.E.P.A 17, 15, 31, 23, 28, 15, 43, 12, 26, 33, 43, 35, 76, 59, 33, 8, 58, 39, 29, 20, 26, 30, 19, 16, 22, 40

Average—32 for first fifteen sentences

C.E.P.B 24, 40, 41, 38, 39, 21, 45, 11, 27, 24, 19, 21, 22, 48, 18, 38, 51, 43, 23, 37, 26, 18

Average—29 for first fifteen sentences

S.S. 13, 26, 21, 34, 34, 18, 12, 20, 24, 14, 35, 51, 18, 18, 52, 31, 49, 35, 33, 51, 23, 24, 22, 12, 32, 24, 22

Average—26 for first fifteen sentences

A *Times* editorial (Figure 7) on a not too complicated subject, a report of the Rockefeller Foundation, is compared with a C.E.P. editorial (Figure 8):

Times editorial 16, 34, 31, 22, 50, 8, 11, 33, 13, 13, 18, 6, 25, 14, 14, 21, 14, 19, 24

Average length—20

C.E.P. editorial 30, 21, 32, 19, 28, 22, 5, 23, 11, 8, 29, 29, 35, 15, 31, 14, 22

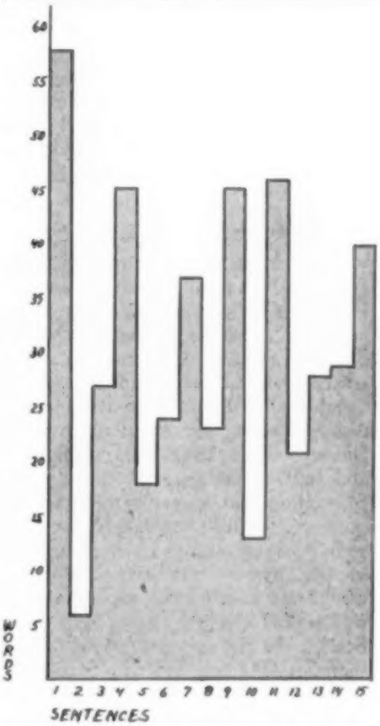
Average length—22

Lincoln's *Gettysburg Address* (Figure 9), widely admired for its clear, simple style, is offered for general comparison:

Lincoln 29, 24, 10, 27, 11, 16, 21, 21, 26, 82

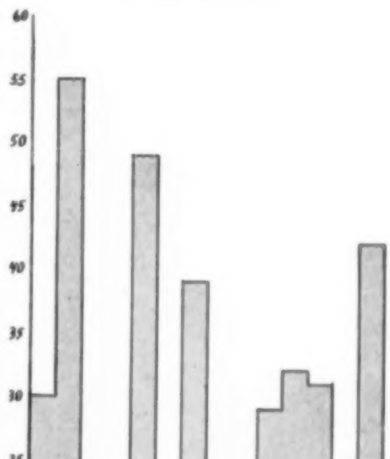
Average length—26

Similarities in average lengths of sentences are striking: *Times*, 30, 29, 27, 20; C.E.P., 32, 29, 26, 22; Lincoln, 26. Still the short sentence is urged indiscriminately upon engineer-writers because, according to the advocates, it is "readable."



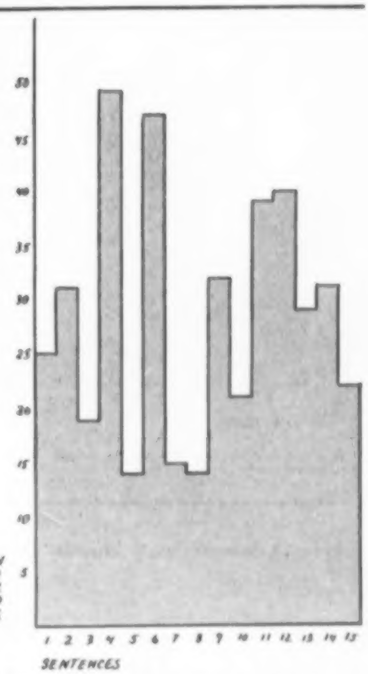
▲ Fig. 1. Sentence length in article A from *The New York Times.*

▼ Fig. 2. Sentence length in article B from *The New York Times.*



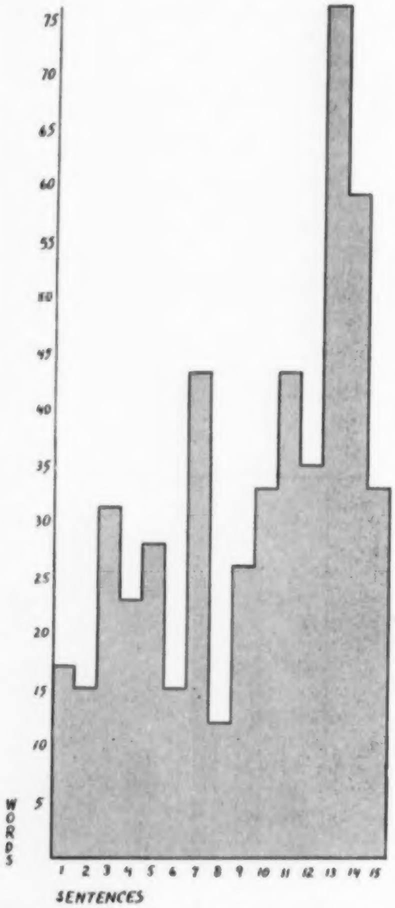
How Short Is Short?

Knowing the importance of precise definition when stating a problem, the engineer asks, "How short is a short sentence? What does *readable* mean?" Shortness and readability are relative terms. The intelligent person's concept of sentence length changes with age, education, and reading experience. One study shows that the sentences written by school children increase in length from an average of 11.1 words in the fourth grade to 17.3 in the first year of high school and 21.5 in the upper terms of college (*5*). The sentence that looks long to a fourth-grade child may look short to a college junior. The man whose only reading is a few letters,



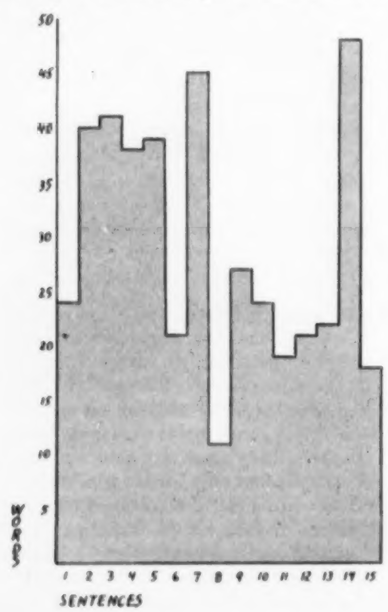
▲ Fig. 3. Sentence length in article C from *The New York Times.*

newspaper headlines, and television captions will find long a sentence that looks short to the reader of current literature. It seems reasonable, therefore, to adjust sentence lengths to readers. A story for children has sentences averaging fifteen words, and newspapers and magazines directed to those of little education use short sentences, but *The New York Times,* C.E.P., and the Symposium Series have longer sentences. In general it is safe to say that sentences in material for educated adult readers may average



▲ Fig. 4. Sentence length in article C.E.P. A.

▼ Fig. 5. Sentence length in article C.E.P. B.



between twenty and thirty words. A higher or lower average indicates that a writer should inspect his sentences critically, but it does not necessarily mean that anything is wrong. Sufficient variety in type, construction, and length is, on the whole, more important than is the average number of words.

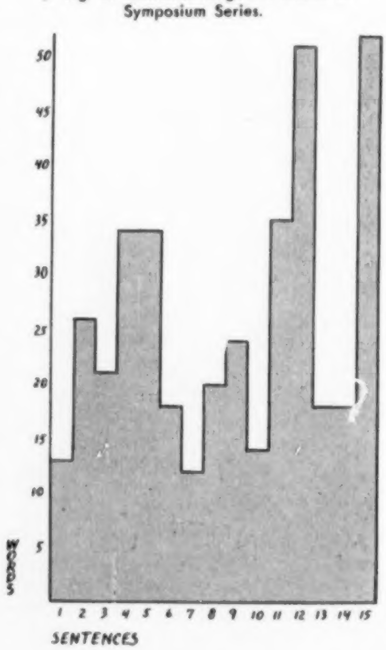
The Reader Dictates

To a certain extent writers, including engineers, naturally adjust sentence lengths to readers insofar as material permits. A chemical engineer at the St. Louis meeting wrote relatively short sentences in his letters to his children about the St. Louis Zoo. His letter to his wife telling her about the trip, explaining some banking arrangements, and relating the news of the wives at convention had longer sentences. The sentences in his convention discussion were probably similar in length to those in his letter to his wife. When the discussion, taken from recording tape, was sent to him for editing before publication, he put together several related thoughts in one sentence and compressed the whole into slightly longer sentences. Much of this adjustment of sentence length to reader he made naturally without any reference to rhetorical principles.

Those Who Demand Primers

The short-sentence addicts would have him go against this natural adjustment of sentence lengths, ignore the standard rhetorics, and make all sentences short. This they expect him to do regardless of his natural style and of the demands of subject matter. Many are the businessmen who would reduce all reading to high-school level. No readers themselves, they find the short sentence easy, just as the school child does, and they would convince the chemical engineer that their needs and desires are universal. Sometimes they even set themselves up as experts on writing and offer jerky, incoherent conglomerations of short sentences as models of prose style. Often they demand that the research scientist adjust the subject matter and style of his reports and technical articles to the twelve-year-old mind. If they dared, they would probably demand that he use comic-book form. They fail to understand that reports written in short sentences and small words by busy scientists will not solve the problem of the man who has poor reading skill; the effort involved in such senseless oversimplification merely wastes the time of the scientist and may give him bad writing habits difficult and expensive to overcome.

▼ Fig. 6. Sentence length in article in Symposium Series.



The man who insists that complex scientific material be simplified for poor readers should hire a writer or cartoonist or both. When he waxes indignant because he has to reread a sentence or two in a technical journal to grasp the meaning, he may be revealing that he wants no reading above the level of the twelve-year-old. He cannot grasp complex ideas, fine distinctions in meaning, adult thinking. There are faults in the writing of the chemical engineers to whom he offers his advice about simplifying, but the greater faults are in him as a reader. It is time that chemical engineers turned the tables and made it plain that whatever mistakes and omissions were made in teaching them to write, the inadequacies in teaching him to read were far greater. Let him learn to read like an educated adult or hire writers to reduce material to childish level for him. At a time when the United States is short 40,000 engineers every year, an insistence that trained, experienced engineers devote time to writing primers is a shocking, stupid waste.

The Crime Against Language

The chemical engineer who tries to suit the style whims of those who demand primer style will soon find himself in the position of the scientists in *Gulliver's Travels*, some of whom were engaged in compressing polysyllables into single syllables while others were striving to abolish words. Swift presents with delightful humor the in-

convenience of substituting objects for words.

> *However, many of the most learned and wise adhere to the new scheme of expressing themselves by things; which hath only this inconvenience attending it, that if a man's business be very great, and of various kinds, he must be obliged in proportion to carry a greater bundle of things upon his back, unless he can afford one or two strong servants to attend him. I have often beheld two of those sages almost sinking under the weight of their packs, like pedlars among us; who, when they met in the streets, would lay down their loads, open their sacks, and hold conversation for an hour together; then put up their implements, help each other to resume their burthens, and take their leave.* (6)

The writer burdened with the obligation of using only short sentences and short words is in danger of sinking, as Swift with the foresight of genius predicted.

But by far the worst danger of the short-sentence and short-word and over-simplification addicts is not that they will eliminate language but that they will reduce it to its least useful and most childish form. Their papers of short sentences spread ideas very thin. Often it takes twice as long to express ideas in short sentences. The loss of subtle distinctions does not trouble the simplification experts who can hardly perceive the most obvious meanings expressed in the most elementary vocabulary and style. What writer can satisfy the industrial engineer who no doubt thought his expression economical when he advertised for a secretary able to write "short basic English"?

Other Influences on Sentence Length

Because a writer may use sentences of various lengths instead of attempting to express every idea in a brief sentence, he should examine the influences on sentence length. The reader has already been considered. Subject matter, type of writing, and the demands of variety and emphasis are also worth study. Even within the field of chemical engineering the demands of subject matter vary. A plea for better salaries for chemical engineers does not require sentences as long as those in an article on heat exchange. A discussion of a new name for a division of the industry may well have shorter sentences than are required for a technical exposition of a project. Type of presentation also influences choice of sentence length. A good speaker will tell an anecdote in relatively short sentences and use longer ones in his argument. Description of apparatus in a technical article may well be given in long sentences which group related details. Informal speaking has the shortest sentences; formal writing, the longest. An explanation to a fellow worker during a coffee break, for example, calls for much shorter sentences than those in a published article. Type of writing means also the writer's natural style. Some men think in terms of groups of related details; others naturally separate small divisions of thought. There is nothing wrong with either style provided that it is not allowed to become monotonous. The writer with a natural tendency to aggregate should practice the short terse sentence, which he may use most effectively for emphasis by contrasting it with long sentences. The writer who naturally places every

Fig. 7. Sentence length in editorial in *The New York Times*.

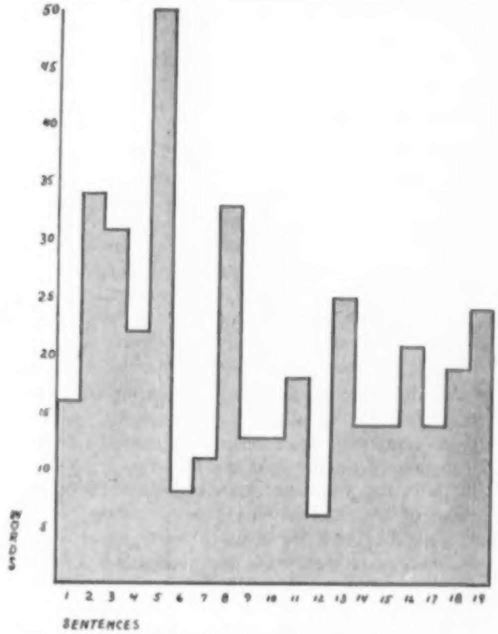
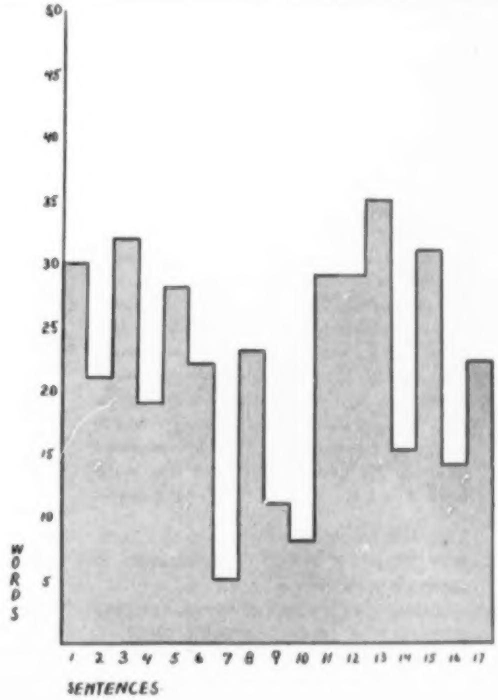


Fig. 8. Sentence length in a C.E.P. editorial.



division of a thought into a separate sentence should try showing relationships by reducing some short sentences to words, phrases, or dependent clauses.

Uses of the Long Sentence

The long sentence is suited to grouping a number of related details clearly, neatly, and economically. The journalist illustrates this when he answers in his first sentence the six essential questions who? what? where? when? why? and how? Causes and reasons, lists, results, characteristics, minor details may all be expressed effectively, tersely, and clearly in long sentences.

To illustrate the advantages of grouping related details, the following four sentences have been compressed into one. In order that the illustration be fair, the four sentences chosen are those of a competent writer on chemical engineering and the changes made are only those necessary for sentence structure.

> The seventeen materials used for study were examined by several methods other than the compression-permeability method, in order to obtain as much information as possible concerning their physical properties. The materials in dry form were examined under the electron microscope, and the photomicrographs of Figures 4 to 7 were taken to establish size and shape of ultimate particles. Nitrogen-adsorption measurements were also made, and specific surface values were calculated for each material, employing the Brunauer-Emmett-Teller method. Air-permeability measurements were made on the dry materials in most cases, using the Fisher subsieve sizer, and the corresponding specific surface was calculated for each by use of the method and slip-flow correction presented by Arnell, and by Carman and Arnell, employing a slip factor Z = 3.5. (1—4 Sentences)

> To obtain as much information as possible about the seventeen materials used for study, they were examined by several methods other than the compression-permeability method: 1) examining the materials in dry form under the electron microscope and taking photomicrographs (Figures 4 to 7) to establish the size and shape of ultimate particles, 2) making nitrogen-adsorption measurements and calculating specific surface values for each material by the Brunauer-Emmett-Teller method, 3) making air-permeability measurements of most of the dry materials by the Fisher subsieve sizer and calculating the specific surface by the method and slip-flow correction of Arnell and Carman and Arnell with a slip factor Z = 3.5. (1—1 Sentence)

The difference in effect and the compression result solely from changes in sentence structure.

Because of its usefulness in bringing a number of related thoughts together, the long sentence is often effective for a summary conclusion. Engineers frequently employ the long sentence for this purpose; in the August, 1953 issue of C.E.P. examples appear in the articles "Mixed-Bed Ion Exchange," "Effect of Packing Size and Column Diameter on Mass Transfer in Liquid-Liquid Extraction," and "Heat Transfer in Packed Beds." When a number of conclusions are to be expressed in one summary sentence, the engineer should try to express them in parallel construction and to arrange them in logical, chronological, or climactic order. A long summary sentence may be emphasized by contrast with several short sentences. The sentence stands out by the bulk of its length, the weight of the important ideas, the careful construction, and the contrast with surrounding sentences. It is a strong ending.

Chopping Up Sentences

A sentence which was used as an example in an article advocating short sentences provides a striking illustration of the economy of the long sentence:

> Although it is possible for the refiner to control the selectivity deterioration by continually discarding a fraction of the catalyst in the unit and replacing it with fresh material of good selectivity, this expedient increases operating costs because of the additional catalyst consumption. (2—Original sentence)

The comment of the article was the following:

> If this sentence is read aloud the reader will be out of breath by the time he reaches the end. This is a fine example of trying to do too much in one sentence. The author has three thoughts here and each one should have its own sentence.
>
> The refiner has a way to keep the selectivity up. He can keep adding fresh catalyst and throwing away part of the old. But this costs him money because he uses more catalyst.
>
> Once more, fewer words, with no sacrifice of meaning spell a gain in simplicity.

No sacrifice of meaning? On two scores objection must be raised—to changes in meaning and to using three sentences to do the work of one.

The original sentence stated, "this expedient increases operating costs"; the revision reads, "this costs him [the refiner] money." There is a decided difference in meaning. The chemical engineer who wrote the original quite properly did not go into the problem in economics of who paid the increased operating costs—refiner, middleman, consumer. The revision changes the meaning by stating that the expedient costs the refiner money. If such carelessness were shown in revising a legal paper, the change in meaning would be serious. The original speaks of "fresh material of good selectivity"; the simplification drops the modification "of good selectivity." Saving three words by discarding them would invalidate a whole experiment if the use of replacement material of average or poor selectivity gave a different result. Reducing length by discarding necessary words is not to be recommended. By failing to convey accurately the exact thought of the original long sentence, these three short sentences illustrate the disadvantages of simplifying too much. Oversimplification not only loses distinctions in thought but soon makes writers insensitive to fairly obvious differences in meaning. There is no point whatsoever in simplifying at the expense of meaning.

The reviser states that the original sentence has three thoughts requiring three sentences, but the thoughts in the original sentence are so closely related that separating them makes them harder rather than easier to read. Only one sentence is needed to express the thought.

> The refiner may maintain selectivity by continually replacing part of the catalyst with fresh material of good selectivity, but he thus increases production costs. (2—Revised)

The original sentence has forty-three words; the revision in three short sentences has thirty-three; the revision in one sentence has twenty-four. The longer sentence is more economical than three short ones. It is shorter even though it includes modifications in meaning which were lost in the three sentences. Here is the answer to the short-sentence addicts.

A writer should never be urged to use short sentences where longer sentences present ideas to his readers more effectively and economically. The chemical engineer writing for a professional journal has intelligent adult readers who should be able to grasp the meaning of (2—Original). Practice and time and effort enable him to reduce his thoughts to (2—Revised). He should not try to write three choppy sentences unless he is writing for people with poor reading skill who do not need to know the finer distinctions in meaning. For his fellow engineers and for the intelligent reader not in the engineering profession a well-constructed sentence of 100 words is clearer than a jumble of short sentences presenting part of the idea in 137 words. Inexperienced writers have as much trouble constructing a series of good short sentences as one good long sentence; therefore they gain nothing by

using the short sentence where it is inappropriate. By selecting the most effective sentence length, the writer makes his own task and the task of the reader easier.

Uses of the Short Sentence

Short sentences have their uses too. A crisp, clear sentence is a good opening, a polished short sentence gives an effect of wit and sparkle, and a terse concluding sentence may be used for sharp emphasis. The short sentence may also be used for effective contrast after a series of long sentences if the important idea appears in the short sentence. The editorial which began

In almost every talk we give, and in many conversations we have with our members on the problems of publishing an engineering magazine, the question is invariably asked, "Why don't you sell more advertising?"

(3—Original)

might have started with the short question,

"Why don't you sell more advertising?"

(3—Revised)

The book review which began

As the authors tell in the preface, this book is not a manual of engineering drawing. Rather it is a summary of the revolution that took place when the General Electric Co. decided to simplify its drafting practices.

(4—Original)

shows an attempt to use a short opening sentence. But a really short one would be more effective,

Here is a revolution in drafting practices.

(4—Revised)

Once the engineer has written a rough draft of a letter or article, he will often find in the first or second paragraph a terse sentence which with a little polishing to shorten it will make a good opening. Few writers automatically begin a first draft with an epigrammatic sentence, but many writers bury among the first ten sentences one that may be reduced in words and sharpened in expression to provide a sparkling opening.

An effect of force and wit is sometimes achieved by a brisk closing sentence. Often brevity is rapierlike in the last sentence of an anecdote. The engineer discoursing on the eccentricities of his first boss may end this way, "And so sometimes before he left a conference the boss would turn to us and say, 'I suppose you fellows all think I'm crazy,' and you know we did think that he was insane." Ending with a terse statement increases the effect, "And so sometimes before he left a conference the boss would turn to us and say, 'I suppose you fellows all think I'm crazy.' We did." This two-word closing gains effectiveness from contrast with the longer preceding sentence. The shorter the sentence the greater the emphasis.

The Unhappy Medium

Because the chemical engineer has been pressed hard and frequently to abandon long sentences and write only short ones, this article has stressed the uses of long and short sentences. As a matter of fact, chemical engineers need to write more long and short sentences instead of their favorite sentence of medium length. Variety in sentence length is much more important than average length. Too much worrying about reducing the average length may lead to the use of short sentences of similar length and construction and result in monotony. Dull paragraphs of sentences formed in one mold are as depressing as the vista presented by a typical cheap housing development—hundreds of houses all the same size, all with the same architectural plan—deadening sameness.

The sentences in Figures 10 and 11 illustrate the point. In Figure 10 are sentences of the first expository paragraphs of an article which offers engineers advice on writing; in Figure 11, the first fifteen sentences of a standard handbook of writing. The author of the sentences in Figure 10 is a chemical engineer who urges the use of short sentences; for a fair comparison sentences from the opening of a standard handbook which does not advocate any particular sentence length are shown in Figure 11. The sentences in Figures 10 and 11 treat similar subject matter—advice to writers. They do not display much variety in type: Figure 10: 9 simple, 5 complex, 1 compound, 0 compound-complex; Figure 11: 8 simple, 4 complex, 1 compound, 2 compound-complex. The slightly greater variety in type in Figure 11 is balanced by three interrogative sentences in Figure 10.

The real difference is in average word length and in variety of sentence length. The sentences in Figure 10 average twelve words. As the dotted line shows, twelve of the sentences have between seven and thirteen words. Sentences so similar act like a drumbeat; they irritate some readers and lull others to sleep. The short-sentence enthusiast forgot that although one short sentence has punch, a series of them can make the reader punchdrunk.

The sentences in Figure 11 average twenty-three words. Individual sentence length varies from six to sixty words, and the author does not group those sentences which might bore the reader

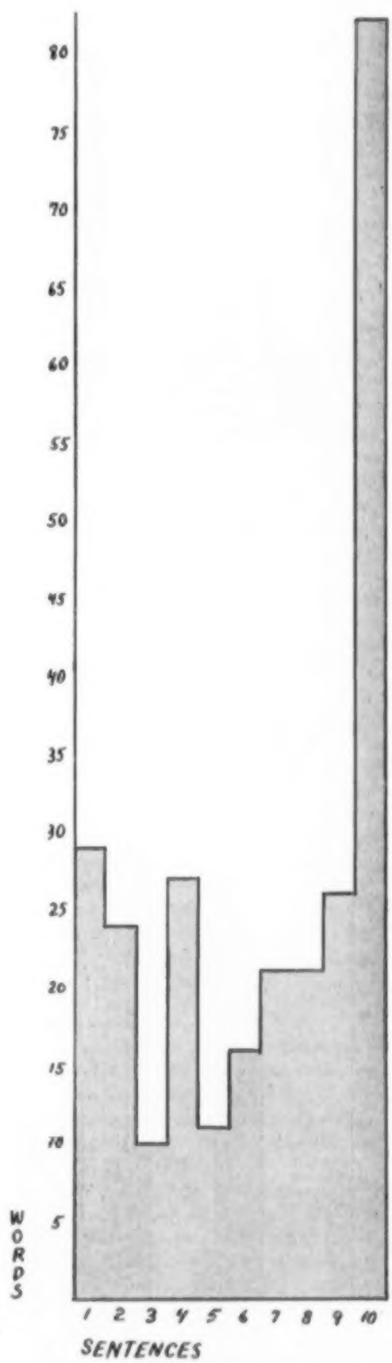
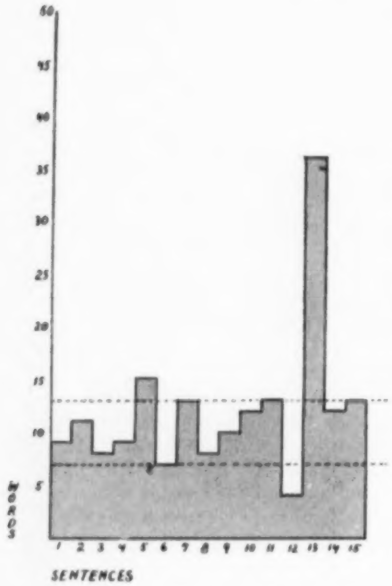
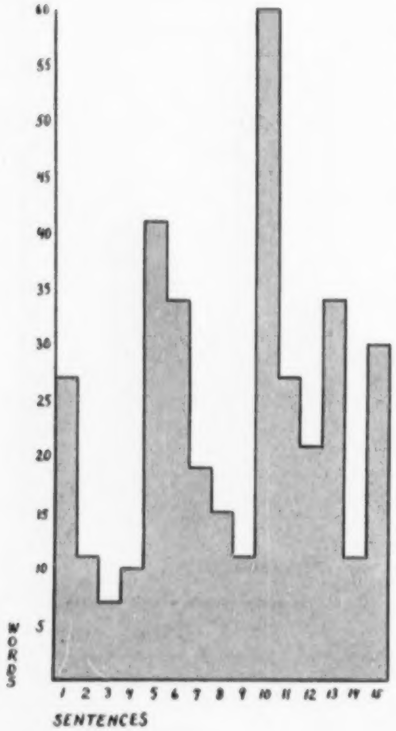


Fig. 9. Sentence length in the Gettysburg Address.



▲ Fig. 10. Sentence length in article on engineers' writing.

Fig. 11. Sentence length in a standard ▼ handbook on writing.



by similarity in length. The flat sameness of the sentences in Figure 10 contrasts with the sharpness and interest of the shifting lengths in Figure 11.

The chemical engineer should not allow himself to be pushed into the rut of monotonous short sentences by advisers who overemphasize the importance of one kind of sentence. The writing of chemical engineers often shows fairly good variation in sentence lengths. Figures 7 and 8 indicate that the C.E.P. editorial writer approaches the *Times* writer in this respect. Figures 4 to 6, which present the C.E.P.*A*, and C.E.P.*B* and S.S. articles previously analyzed, have adequate variety, C.E.P.*A* (Figure 4) and S.S. (Figure 6) being better than C.E.P.*B* (Figure 5); the *Times* articles previously discussed (Figures 1 to 3) have sharper variety in sentence length. For general comparison the *Gettysburg Address* is presented in Figure 9. The writing of the engineers needs the spice of very short and very long sentences.

Many sentences of any one length are dull unless the writer skillfully varies sentence structure. Using different lengths is often easier than varying structure; therefore this article has analyzed variety in length. Sentences also gain interest and emphasis from variety in rhetorical structure (loose, periodic, balanced); in grammatical structure (simple, complex, compound, or compound-complex); in mood (declarative, interrogative, exclamatory, imperative); in order (normal, inverted); and in elements (words, phrases, clauses). The engineer who wishes to review these forms will find them defined and illustrated in standard handbooks of writing. A number of handbooks will be listed and considered in Part III of this series.

First and Last Impressions

Published engineering papers show a strong need for variety in sentence beginnings. Too frequently engineer-writers begin sentences of similar lengths with subjects or with conjunctions like *however* and *hence* followed by subjects. There are many ways of beginning any one sentence, as the following illustrations show. The original sentence in each case is taken from an article on chemical engineering.

This gadget, marketed under the name of Glamorglow, was first offered to industry in the fall of 1950 after a period of development and laboratory tests. (5)

Marketed under the name of Glamorglow, it was first offered to industry in the fall of 1950 after a period of development and laboratory tests. (5)

In the fall of 1950 after a period of development and laboratory tests, this gadget, marketed under the name of Glamorglow, was first offered to industry. (5)

After the gadget had been developed and tested in the laboratory, it was offered to industry under the name of Glamorglow in the fall of 1950. (5)

First offered to industry in the fall of 1950 after a period of development and laboratory tests, this gadget was marketed under the name of Glamorglow. (5)

Accurate prediction of either bubble-cap or perforated-plate behavior is complicated by the large number of variables which must be considered. (6)

Because of the large number of variables which must be considered, accurate prediction of either bubble-cap or perforated-plate behavior is complicated. (6)

The large number of variables which must be considered complicates accurate prediction of either bubble-cap or perforated-plate behavior. (6)

Because a large number of variables must be considered, accurate prediction of either bubble-cap or perforated-plate behavior is complicated. (6)

It being necessary to consider a large number of variables, accurate prediction of either bubble-cap or perforated-plate behavior is complicated. (6)

The writer who has limited time for revision should first make sure that his sentences are correct and then devote his time to the most important sentences. These are the first and last sentences of the paper and the first and last sentences of each paragraph, key sentences which should contain important ideas. They deserve the reviser's labor because they get the reader's attention.

Devices for Emphasis

A sentence which is different from its neighbors will stand out. A sentence containing a major idea may be given emphasis by contrasting it in length with surrounding sentences. If it is noticeably shorter or longer, it will attract attention. Lincoln's *Gettysburg Address*, for example, which has an average sentence length of twenty-six words, focuses attention on the eighty-two word closing. Fortunately Lincoln is not writing at a time when advocates of the short sentence prove by equations that eighty-two words are far too many for one sentence. Fortunately no sentence chopper can split the ending:

> It is rather for us to be here dedicated to the great task remaining before us,—that from these honored dead we take increased devotion to that cause for which they gave the last full measure of devotion—that we here highly resolve that these dead shall not have died in vain—that this nation, under God, shall

have a new birth of freedom—and that government of the people, by the people, for the people, shall not perish from the earth.

Other differences in form may be used for the same effect. The different sentence attracts attention—a periodic sentence surrounded by loose sentences, a complex sentence in a series of simple sentences, a question in a declarative paragraph. Placing the main thought in a sentence different from the surrounding sentences stresses the principal thought.

Beginning and ending sentences with important words also achieves proper emphasis. Whenever possible, elements of minor importance should be tucked away in the middle of the sentence. The conjunctions with which chemical engineers very often begin sentences should be buried in midsentence. Attention to beginnings and endings will help the engineer shape better sentences.

It is always simplest to hire men who are already specialists either through training in some school or through actual experience in some specific industry following graduation from college. (7—Original)

Hiring specialists with postgraduate education or specific industrial experience is always simplest. (7—Revised)

This paper is based on the study of the commercial problem, solved by use of an analogue computer, of predicting the proper design for an exchanger involving three fluids: air, nitrogen, and oxygen. (8—Original)

The commercial problem of predicting the proper design for an exchanger involving the three fluids air, nitrogen, and oxygen is solved by the use of an analogue computer. (8—Revised)

Sentence 8—Revised illustrates how naturally one may place meaningful words first and last in an English sentence. Often idiom seems to demand such placing.

Excess Verbiage

Chemical engineers seem fond of burying ideas in unnecessary words. Sometimes a manuscript editor concludes that no self-respecting chemical engineer will ever use one word where he can possibly squeeze in six words. The following examples show this tendency to spread ideas thin:

Prior to the start of this experiment (9—Original)

Before this experiment (9—Revised)

The statement enumerates six adverse conditions that are said to depress, today, incentive of our citizens to invent. (10—Original)

The statement enumerates six adverse conditions that discourage inventing. (10—Revised with a slight change in meaning)

. . . proceed to this further step of written communication (11—Original)

write (11—Revised)

. . . for most engineering calculations for calculating vapor enthalpies (12—Original)

. . . for most engineering calculations of vapor enthalpies (12—Revised)

It should leave no room for double interpretation. (13—Original)

It should leave no room for ambiguity. (13—Revised)

In experiments with water, the liquid was thoroughly boiled to get rid of any air bubbles. (14—Original)

The water was thoroughly boiled to eliminate air bubbles. (14—Revised)

To make doubly sure no leaks occur, a bead of adhesive is run around the edges of the filter on both sides. (15—Original)

To avoid leaks the filter is edged with a bead of adhesive. (15—Revised)

It is not desirable to leave filters in a system after the resistance has increased to the point where there is a substantial decrease in the flow of air. (16—Original)

Filters should not be left in a system after resistance has caused a substantial decrease in the flow of air. (16—Revised)

A more rigorous derivation would be extremely complicated, and would hardly be justified in view of uncertainties existing with respect to basic information necessary for practical use of the result. (17—Original)

A complicated, more rigorous derivation is not justified while basic information for practical use of the result is uncertain. (17—Revised)

First, the liquid-phase composition establishes the convergence pressure, and second, for the light components, particularly hydrogen and methane, it modifies their *K* values. (18—Original)

The liquid-phase composition establishes the convergence pressure and also modifies the *K* values of the light components, particularly hydrogen and methane. (18—Revised)

On the basis of the foregoing discussion it is apparent that . . . (19—Original)

This discussion shows . . . (19—Revised)

I can take either side of the question and argue with some conviction. (20—Original)

I can argue either side of the question with some conviction. (20—Revised)

The writer who thinks that excess verbiage lends tone or elegance to his writing is mistaken. The result of piling unnecessary words into sentences is diluteness. The thought is so weakened that it has the effect of two drops of Scotch in a glass of soda. This tendency to spread the idea thin is at its worst when combined with a penchant for short sentences which require repetition, as the following example shows:

As the pressure is increased inside the pressure bomb, more pressure is applied to the window, and, in turn, to the sealing rings. These are made of thin neoprene rubber. The internal pressure causes the neoprene rings, of which there are two, to spread out to make a seal on the one side with the Lucite rod and with the wall of the cylinder on the other. (21—Original)

As the pressure in the bomb is increased and is applied first to the window and then to the two thin neoprene rubber sealing rings, the rings spread and form a seal on one side with the Lucite rod and on the other with the wall of the cylinder. (21—Revised)

Revision That Cheers

The writer who is not in the habit of revising may at this point be appalled at the time and effort involved in correcting and improving sentences. The only comfort for him is the fact that intelligent attention to the suggestions given will bring satisfying results and to a certain extent the work will be fun. Beginners often learn by writing each sentence ten different ways; successful authors spend as much as an hour on the revision of one sentence. If the chemical engineer will take his best report and try writing the sentences as many different ways as possible, he will be pleasantly surprised not only by the improvement in his writing but by the enjoyment he finds in revising. Revision is dull only when the writer works without any idea of what to look for and how to improve. As soon as he understands a few basic principles, he works with a purpose and the encouragement of his progress will keep him going even when a sentence proves especially recalcitrant. In fact, at that point he will dig in, determined to lick the sentence if it takes all night. He will succeed long before the dawn.

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[The third and concluding article of this series will consider the engineer and the right word, a comma that changes meaning, the true you-approach, reading for better writing.]

ALUMINUM ALLOY REFERENCE SHEET

HARRY W. FRITTS — Aluminum Company of America, New Kensington, Pa.

Wrought Alloys 61S and 63S

Commercial Products:

61S—Sheet, plate, wire, rod, bar, tube, pipe, rolled shapes, extrusions, forgings.
63S—Tube, pipe, extrusions.

Applications and Remarks: Alloy 61S is used in the process industries for piping, tankage, fittings, tread plate, and for general structural and architectural applications where good resistance to corrosion and high strength are required. Alloy 63S is principally used for architectural shapes and for tube and pipe where light weight, low cost, good strength, and good resistance to corrosion are required. Both of these alloys are heat-treatable, therefore, heat-treating after welding may be necessary to develop the maximum properties. Alloy 61S-T6 structurals, riveted, bolted, or tack welded, are widely used for supporting tanks, process equipment, walkways, etc. Both of these alloys are included in section 8 of the 1952 A.S.M.E. Boiler and Pressure Vessel Code.

Composition:

61S—0.25% Cu, 0.6% Si 1.0% Mg, 0.15% Cr, balance Al
63S—0.4% Si, 0.7% Mg, balance Al

Formability: Both alloys have good formability. Severe forming should be performed with the annealed or as-fabricated material. Alloy 61S in the —T4 and —T6 tempers has good machining properties. High machine speeds are possible using a high rake angle. Alloy 63S in the —T5 and —T6 tempers is similar to 61S in machinability.

Heat Treatment: Wrought 61S and 63S are both heat-treatable alloys. Alloy 61S is commonly supplied in the annealed (—0) temper, in the —T4, solution heat treated, and —T6, solution heat treated and then artificially aged tempers. Alloy 63S is normally supplied in one of the following tempers: —T42 or as-fabricated, —T5 or artificially aged, —T6 or solution heat treated and artificially aged, and —T83 or solution heat treated, cold worked, and the artifically aged.

Weldability: Alloys 61S and 63S can be welded by all the common methods using 43S welding wire. Alloy A54S wire also can be used where greater elongation is desired. Maximum properties through the weld area can be obtained by heat treating after welding. Where such a procedure is impractical, it often is possible by strategic location of joints to utilize the full properties of the parent material. Inert gas shielded arc-welding processes are preferred because they minimize the extent of the heat-affected zone and the distortion, and prevent flux contamination.

ALUMINUM ALLOY

A.S.T.M. DESIGNATIONS:

61S — GS11A

63S — GS10A

A.S.T.M. SPECIFICATIONS:

B178, B209, B210, B211, B221, B235, B241, B247, B273, B274, B221, B235, B241, B274

MECHANICAL PROPERTIES:

	Temper Designations					
	61S			63S		
	—0	—T4	—T6	—T42	—T5	—T6
Tensile strength, lb./sq.in.	18,000	35,000	45,000	22,000	27,000	35,000
Yield strength, lb./sq.in.	8,000	21,000	40,000	13,000	21,000	31,000
Elongation—% in 2 in. (1/16 in. sheet)	22	22	12	20	12	12
Shear strength, lb./sq.in.	12,500	24,000	30,000	14,000	17,000	22,000
Brinell hardness—500 kg. load, 10-mm ball	30	65	95	42	60	73

PHYSICAL PROPERTIES:	61S	63S
Modulus of elasticity, lb./sq.in.	10,000,000	10,000,000
Specific gravity	2.70	2.70
Weight—lb./cu.in.	0.098	0.098
Melting range, °F.	1080°-1205°	1140°1205°
Thermal conductivity—B.t.u./(hr.) (sq.ft.) (°F./in.)	1190 (—0) 1074 (—T 4 & —T6)	1335 (—T42) 1452 (—T5 & —T6)
Average coefficient of thermal expansion—in./°F. x 10^{-6}		
−76° — +68°	12.0	——
68° — 212°	13.1	13.0
68° — 392°	13.5	13.5
68° — 572°	14.1	14.0
Electrical conductivity—% of International Annealed Copper Standard	45 (—0) 40 (—T4 & —T6)	50 (—T42) 55 (—T5 & —T6)

CORROSION RESISTANCE

Acids

Acetic, all concs., r.t.*	E
Acetic, other than glacial, boiling	P
Acetic glacial, boiling *	E[1]
Acetic anhydride, r.t.*	E
Acrylic, glacial, r.t.*	E
Benzoic, sat. soln., boiling *	E
Boric, 7% soln., 180° F.*	E
Butyric, all concs., r.t.*	E
Butyric anhydride, r.t.*	E
Carbolic (phenol), all concs., to 240° F.*	E
Carbonic, all concs., r.t.*	E
Chromic, below 10%, r.t.	G
Cresylic (Cresol), r.t.	E
Fatty, up to boiling *	E[1]
Hydrochloric, all concs.	N
Hydrocyanic, all concs., r.t.*	E
Hydrofluoric, anhydrous, 200° F.	E
Hydrofluric solutions	N
Lactic, anhydrous, r.t.*	E
Lactic, up to 10%, r.t.	E
Maleic, 30%, r.t.	E
Maleic anhydride, molten *	E
Malic, to 50%, r.t.	E
Naphthenic, up to 180° F.*	E[1]
Nitric, above 82%, to 120° F.*	E
Nitric, below 82%, r.t.	P
Nitric, Red Fuming, up to 120° F.*	E
Oleic, up to boiling *	E[1]
Oxalic, all concs., r.t.*	G
Oxalic, all concs., elevated temperature	P
Phosphoric, all concs.	N
Phthalic, molten	E
Phthalic anhydride, molten *	E
Propionic, all concs., r.t.*	E
Propionic anhydride, r.t.*	E
Stearic, up to boiling *	E[1]
Sulfuric, fuming	G
Sulfuric, other than fuming	N
Sulfurous, r.t.	F
Tannic, all concs., pure, r.t.	E
Tartaric, all concs., r.t.*	E

Alkalies

Ammonium hydroxide, comm'l., r.t.*	E
Calcium hydroxide, all concs.	P
Potassium hydroxide, all concs.	N
Sodium hydroxide, all concs.	N

Alkaline Salts

Potassium carbonate, all concs.	P
Sodium bicarbonate, r.t.	E
Sodium carbonate, all concs.	P
Sodium sulfide	P

Neutral Salts

Calcium chloride, all concs., to 200° F.	G◦[2]
Calcium sulfate, sat. soln., r.t.*	G◦
Calcium sulfide, all concs., r.t.*	G
Magnesium chloride, all concs., r.t.	G◦
Magnesium sulfate, to 50% soln., r.t.	G
Potassium chloride, all concs., r.t.	G◦[2]
Potassium nitrate, all concs., r.t.	E
Potassium sulfate, all concs., r.t.	E
Sodium chloride, all concs., r.t.*	G◦[2]
Sodium nitrate, all concs., r.t.*	E
Sodium sulfate, all concs., r.t.*	E

Acid Salts

Alum, paper makers, r.t.*	E
Aluminum chloride, dry, 70° F.	G
Aluminum chloride, moist	P
Aluminum sulfate, r.t.*	E
Ammonium chloride, all concs., r.t.*	G◦
Ammonium nitrate, all concs., to 285° F.*	E
Ammonium sulfate, all concs., r.t.*	E
Copper chloride, nitrate, sulfate	P◦
Ferric chloride, nitrate, sulfate	P◦
Lead chloride, nitrate, sulfate	P◦
Mercury salts	N◦
Nickel chloride, nitrate, sulfate	P◦
Silver salts	P◦
Stannous and stannic salts	P◦
Zinc chloride	P◦

Gases

Acetylene, dry *	E
Air, wet or dry, hot or cold *	E
Ammonia, dry *	E
Bromine	N
Carbon dioxide, wet or dry, hot or cold *	E
Chlorine, wet or elevated temps.	N
Freons *	E
Hydrogen sulfide, wet or dry, hot or cold *	E
Nitrogen, wet or dry, hot or cold *	E
Oxygen, wet or dry, hot or cold *	E
Sulfur dioxide, dry	E
Sulfur dioxide, wet	F

Organic Materials

Acetone, r.t.*	E
Alcohols, methyl, ethyl, etc., pure, r.t.*	E
Aniline, all concs., to 212° F.	G
Benzaldehyde, r.t.*	E
Benzene, to boiling *	E
Carbon disulfide, to boiling *	E
Carbon tetrachloride, dry, r.t.*	E
Chloroform, dry, r.t.	E
Ethyl acetate, pure, r.t.	E
Formaldehyde *	G◦
Furfural, r.t.*	E
Gasoline, to boiling *	E
Glycerine, to boiling *	E
Glycols, ethylene and propylene, r.t.*	E
Mercaptans, amyl, r.t.*	E
Methyl ethyl ketone *	E
Oils, crude, essential, refined, vegetable *	E
Oils, sour crude (H_2S)*	E
Trichloroethylene, dry, r.t.*	E

Pickling Operations

Acetic acid (Mag. Products)*	E
Sulfuric plus dichromate	N
Sulfuric plus hydrochloric	N

Food Industry

Brines, inhibited *	E
Edible oils and fats *	E
Fatty acids *	E
Fruits and fruit juices *	G
Vegetables *	G
Milk products *	E
Beer*	E

Paper Mill Applications

Kraft liquor	N
Black liquor	N
Green liquor	N
White liquor	F◦
Sulfite liquor	P
Chloride bleach solution	P
Chloride bleach vapors	G
Hydrogen peroxide (above 30%)*	E
Paper makers alum *	E
Humid and chemical atmospheres *	E

Photographic Industry

Humid atmospheres *	E
Cellulose acetate *	E
Acetic anhydride *	E
Developers	P
Silver nitrate	P◦
Solutions containing SO_2	P

Fertilizer Industry

Ammonia, anhydrous *	E
Ammoniated ammonium nitrate *	E
Urea *	E

* Aluminum alloys used commercially.

◦ Subject to pitting-type corrosion.

[1] Must have trace of moisture present at boiling temperature.

[2] May be inhibited with sodium chromate.

RATINGS:

E—*Excellent resistance. 0.004 max. in./year of penetration. Corrosion so slight as to be harmless.*

G—*Good resistance. 0.004-0.048 in./year of penetration. Satisfactory service expected; at most a slight etch.*

F—*Fair resistance. 0.048-0.120 in. of penetration/year. Satisfactory service under specific conditions. Light to moderate attack.*

P—*Poor resistance. 0.120-0.420 in. of penetration/year. Satisfactory for temporary service only.*

N—*Aluminum not recommended. Rate of attack high.*

r.t.—*Room temperature.*

No. 32

Storrowton, on the grounds of the Eastern States Exposition, is a reproduction of an old New England village.

New England in the Spring

by HAROLD J. WHITMAN, Monsanto Chemical Co., Springfield, Mass.

The May 16-19 Spring National Meeting of A.I.Ch.E. in Hotel Kimball, Springfield, Mass., will be an experience long to remember. Whether travelling by air or land, the approach itself will give everyone an opportunity to see the beautiful New England countryside at its best. The bright green of Pioneer Valley meadows will contrast with the purple of Berkshire Hills to provide a rare scenic effect not only to the camera enthusiasts, but also to all nature-loving chemical engineers and their wives. And in the Springfield area in particular, winding country lanes are rich with farmhouses with their connecting barns, old inns, and other evidences of early American graceful living, which fill so many pages of guidebooks.

Located on the broad Connecticut River, Springfield was settled in 1636, only sixteen years after the Pilgrims landed on Plymouth Rock. Today, it is known as a city of beautiful homes. Its suburb to the south, Longmeadow, represents one of the most stately outlays of meticulously preserved colonial homes, each with its unobtrusive sign proudly announcing its date of construction—often revealing ages of approximately 150 years!

The city itself pays serious homage to the past, and yet it is in every way a modern industrial city with a total of 488 establishments making as many different product lines! Westinghouse appliances, Bosch magnetos, Indian motorcycles, Smith & Wesson revolvers, Springfield and Garand rifles, Absorbine Jr. liniment, Monsanto Chemical plastics, Worthington pumps, Strathmore papers, Chapman valves, Milton Bradley games and toys, Buxton billfolds, G & C Merriam's dictionaries, Stanley home products and Bigelow-Sanford carpets are typical examples.

Such is the environment for the spring meeting, which in itself offers major attractions to chemical engineers of widely varied interests. Co-chairman Francis E. Reese and Eli Perry, of Monsanto Chemical Co., together with Technical Program Chairman E. Bryant Fitch of Dorr Co., have been successful in lining up an outstanding fare of papers.

General Program

The program will warm up at 3:00 P.M. on Sunday afternoon, May 16, with a forum—"Training for Industry Freshmen—What Kind and How Much?" This will be a panel discussion of the pros and cons of formal training programs for neophyte chemical engineers and will be moderated by John E. Sutcliffe, industrial relations director of Chain Belt Co. The forum will be followed by an informal get-acquainted hour of the cocktail party variety at 8:00 P.M.

On Monday morning at 9:30 A.M., after a welcome by the technical program chairman, E. Bryant Fitch, of the Dorr Co., a symposium on process

SPRINGFIELD . . . A MODERN CITY LOYAL TO THE TRADITIONS OF ANOTHER AGE

One of the buildings at Sturbridge Village.

Air view of Springfield (looking north)

Old First Church on Court Square

design will get underway, followed in the afternoon by a general technical session with Eli Perry of Monsanto as chairman. The banquet will be held Monday night at Kimball Hotel at 7:30 P.M.

The Symposium on Process Design, with W. W. Kraft of The Lummus Co. as chairman, has been described as being three fourths devoted to borderline-decision situations confronted by process designers. Among the aspects dealt with are: factors of decision between continuous and batch operation; between proceeding into full-scale design vs. reverting to more pilot-scale experimentation; between being concerned about traces of contaminants, or relegating them to the "unimportant" category. In addition, there will be a paper which brings up to date the available information on process design of light hydrocarbon cracking units, a subject of widespread interest in these days of petrochemical processing trends.

On Tuesday morning, a Symposium on Cost Controls in Operation, with D. A. Dahlstrom of The Eimco Corp. and F. A. Fisher of Sinclair Research Lab., Inc. as chairmen, will deal with the practical aspects of this all-important subject. Research, construction and production will come under analysis during this session, and a paper on the use of statistical methods will present specific techniques which can be employed. The session will wind up with a luncheon at which Daniel M. Sheehan, vice-president and comptroller, Monsanto Chemical Co., will be the speaker.

The Symposium on Polymeric Materials of Construction, with C. C. Winding of Cornell University as chairman, will summarize chemical engineering use of potential qualities of this family of construction materials, which has already shown such value.

A general technical session on Wednesday morning with E. E. Lindsey of U. of Mass. as chairman, completes the technical program. (Note that there are no concurrent sessions).

REGISTRATION AND INFORMATION

Vice-Chairman Howard L. Minckler, Monsanto Chemical Co., says that his right-hand man (Donald V. Bierwert, Monsanto Chemical Co., chairman of the Registration Committee) has established a speedy processing system for all preregistrants. (Preregistration cards are enclosed with the Official Program).

An information center will be operated in conjunction with the registration desk as will an exchange desk which can take care of any changes members and visitors might wish to make on preregistered functions.

HOUSING

Hotel reservations must be in early. That's the word from John E. Swan, Monsanto Chemical Co., chairman, Housing Committee. Although there will be room for all, the most desirable rooms (we think he means the rooms with beds—Ed.) will go to the early birds. Since this will be a large meeting, reservations will take most of the rooms in the local hotels. Doubling up in rooms with a member of your choice will be a big help.

All meetings will be held at the Hotel Kimball. It is important, therefore, if a visitor plans to stay there, to put in his reservations on receipt of the official program which has the reservation cards attached.

Banquet

The Entertainment Committee has arranged a banquet for Monday evening. Paul Klingsporn, chairman of that committee, has promised as guest speaker an officer of the State Department who will bring a timely message.

(Continued on page 66)

Springfield plants of Monsanto Chemical Co. and Shawinigan Resins Corp.

TECHNICAL PROGRAM

Monday, May 17, 1954

TECHNICAL SESSION No. 1

Symposium on Process Design

Chairman — W. W. Kraft, The Lummus Co.

9:45 A.M.

AN ANALYSIS OF THE PRINCIPLES OF BATCH AND CONTINUOUS OPERATION, A. Klinkenberg; N. V. de Bataafsche Petroleum Maatschappij, The Hague.

EXTRAPOLATION LIMITS FOR PROCESS EQUIPMENT, Laurent Michel, Robert D. Beattie, Thomas H. Goodgame; Godfrey L. Cabot, Inc., Cambridge, Mass.

THE INFLUENCE OF CONTAMINANTS ON PROCESS DESIGN AND ECONOMICS, B. J. Mayland, R. M. Reed, and N. C. Updegraff, The Girdler Co., Louisville, Ky.

PROCESS DESIGN OF LIGHT HYDROCARBON CRACKING UNITS, James R. Fair, Humble Oil Co. Fellow, University of Texas, Austin, Tex.; Howard F. Rase, University of Texas, Austin.

TECHNICAL SESSION No. 2

General Technical Program

Chairman—E. Perry, Monsanto Chemical Co.

2:00 P.M.

EUROPEAN DESIGNS OF ELECTROLYTIC CELLS FOR THE MANUFACTURE OF CHLORINE AND CAUSTIC, N. A. J. Platzer, Monsanto Chemical Co., Springfield, Mass.

THEORY AND PRACTICE OF CONTINUOUS PRESSURE FILTRATION, N. Nickolaus, The Eimco Corp., New York, N. Y., and D. A. Dahlstrom, The Eimco Corp., Chicago, Ill.

THE ROLE OF POROSITY IN FILTRATION, PART II—ANALYTICAL EQUATIONS FOR CONSTANT RATE FILTRATION, F. M. Tiller, Lamar State College of Technology, Beaumont, Tex.

THE FLOW OF NON-NEWTONIAN FLUIDS IN CIRCULAR CONDUITS, N. W. Ryan, University of Utah, Salt Lake City; W. E. Stevens, Humble Oil Co., Baytown, Tex., and E. B. Christiansen, University of Utah.

AN AUTOMATIC LABORATORY DISTILLATION COLUMN AND ITS OPERATING CHARACTERISTICS, G. A. Latinen, Monsanto Chemical Co., Springfield, Mass.

Tuesday, May 18, 1954

9:00 A.M.

TECHNICAL SESSION No. 3

Symposium on Cost Controls in Operation

Chairmen—D. A. Dahlstrom, The Eimco Corp., and F. R. Fisher, Sinclair Research Lab., Inc.

(Continued on page 67)

more than 50 years of experience in designing and building dryers for industry . . .

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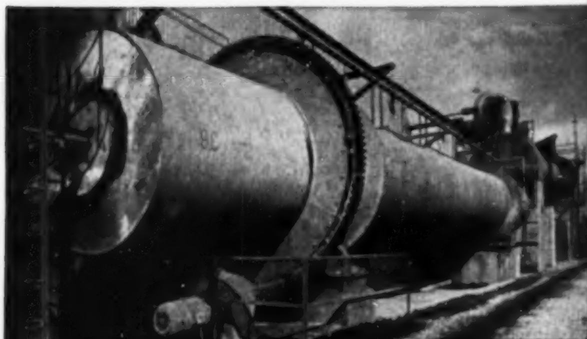

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NATIONAL MEETING Report

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

By John Mellecker

Washington, D. C.: Early Spring 1954—Largest National Meeting in the history of A.I.Ch.E.! Registration 1,254 . . . Smyth of A.E.C. announced Government five-year nuclear reactor development program . . . 46 technical papers on subjects ranging from future of fertilizer industry to the use of a computer in place of a pilot plant! Weather: Perfect.

NUCLEAR POWER STATUS was covered by two industrialists, a distinguished scientist, a lawyer, and a congressman . . . an excellent prelude to the First International Conference on Nuclear Engineering to be held in Ann Arbor, June 20-25 (sponsored jointly by A.I. Ch.E. and the University of Michigan).

W. C. Asbury (Standard Oil Development) led the Symposium on Nuclear Power, which was addressed by E. J. Putzell, Jr. (Monsanto), T. S. Kenyon (New York Patent Law Assn.), R. P. Peterson (A.E.C.), and Carl Hinshaw (Representative from Calif.) . . . Asbury, Putzell and Kenyon voiced different approaches to one general request: Revise liberally the Atomic Energy Act, to give industry the incentive and freedom it must have (and deserves) to bring its resources to bear in the nuclear race . . . Rep. Hinshaw, a member of the Joint Congressional Committee on Atomic Energy, pointed out the vastness of our nuclear program (larger than many of our largest manufacturing firms combined), and cited pressures apt to mean compromise in the Administration's program for revision of the law . . . Peterson, chief of Industrial Reactors Branch, A.E.C., confirmed the gravity of the problems delaying economic power from the atom, but held out hope through development of the "breeder"-type reactor, and application of chemical engineering techniques.

SMYTH, member of the Atomic Energy Commission, announced at the banquet the Government's decision to proceed at once with a five-year plan that calls for four more major reactors. One of these would pass steam, generated in the reactor core, directly through the turbine—eliminating extensive heat-exchange equipment, if it works. Program is set up to resolve what now appears to be major reactor problems in power program.

TARIFF confusion motivated Senator Symington (Mo.) to speak for effective barriers in cases where entry into this country would cause hardship and for no barriers against items needed by our industries, to expedite research, or to ensure national security.

NO WORRY ABOUT FUTURE OF CHEMICAL ENGINEERING was the opinion of Commerce Under Secretary Walter Williams, himself a chemical engineering graduate. He listed our needs for the future as: nuclear power, conservation of fossil fuel resources, conversion of agricultural surpluses, economic processing of marginal ores, and utilization of "wastes."

NATIONAL SCIENCE FOUNDATION is to have greater responsibility for the Government's research and development support program, according to Defense Asst. Secy. Donald Quarles, who also belabored what he termed our tendency to reveal too many of our scientific secrets to the enemy.

FERTILIZERS are destined to occupy a more important position because of the growing pressure of population with a nearly static tillable land acreage, according to E. C. Kapusta of National Fertilizer Association, speaking at G. L. Bridger's (Iowa State) symposium.

Breakdown of the above industry, and its progress are as follows: (1) *nitrogen compounds*, undergoing increasing output, (2) *phosphatic materials*, converting to continuous operating plants, as well as concentrating product, (3) *potassium compounds*, producing more highly refined products, (4) *mixed fertilizers*, already entailing 1,200 plants and producing 70% of total product, converting to continuous processes, improving flowing and storing qualities of products, and incorporating wetting agents. . . . Also described was a new Chemico Urea Process (Cook, Chemical

▲ Address by Defense Asst. Secy. Quarles.

▼ Sunday evening get-acquainted party.

▲ H. D. Smyth addressing banquet assembly.

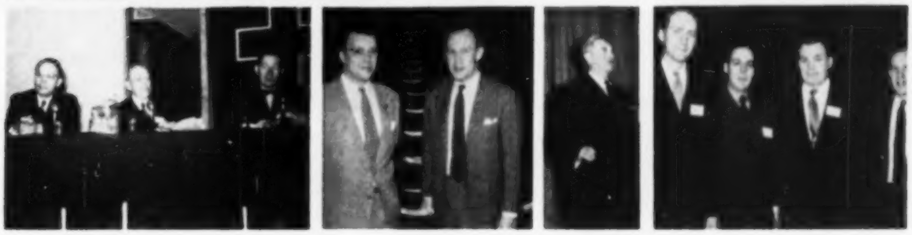
▼ Plant trips.

▲ Council in session.

▼ Radio: C. P. Beazley with speaker, F. O. Rice.

Some of those who made the meeting possible: (l. to r.) G. Armistead, Jr.; E. J. Joblonski; Mr. & Mrs. G. W. McBride; Mrs. W. J. Murphy; W. J. Murphy.

Mr. & Mrs. P. H. Groggins; A. C. Scurlock & K. Hardy. Press Room Scene: E. Reardon, T. Stevenson, D. Cromlin; Mr. & Mrs. D. O. Myatt.



Nuclear Power Panel: E. J. Putzell, Jr., T. S. Kenyon & R. P. Peterson; R. D. Sheeline & J. P. Ekberg, Jr.; U. S. Senator Symington; General Technical Session: R. H. Wetzel, I. Leibson, F. A. Landee, J. P. Ekberg, Jr.

Construction Corp.) . . . Several improvements in existing types of specialized industry equipment were brought out in two papers (Yates, Nielsson & Hicks of TVA; Martenet of Rauh & Sons).

COMPUTER REPLACES PILOT PLANT—Long a dream, now a reality, reported by Du Pont chemical engineers working with the MIT "Whirlwind"—(Gee, Linton, Maier & Raines, polychemicals dept., Wilmington) in Wayne C. Edmister's (Calif. Res. Corp.) Symposium on Use of Computing Machinery.

This significant development involved a tubular reactor system around which they formulated 50 runs (50 sets of conditions) . . . One of the experienced men from the plant operated the computer for certain of the runs and remarked that "the response from the computer was the same in almost every respect as in the operation of the actual plant!" The computer took 42 hr.; hand solution would take one man 20 years and actual semiworks duplication of these runs "several years". . . .

WHAT KIND OF COMPUTER TO USE (analog vs. digital, etc.) was dealt with by Beutler (Du Pont engineering dept., Wilmington). . . . The Dow computation laboratory in Midland, Mich., was described by F. A. Landee as handling a wide variety of technical and business problems. . . .

A Card Programmed digital machine and an EASE analog computer are used. The former is leased for about $2,500 a month; the latter was purchased for $10,000. Four persons operate the service, one a mathematician. Decision on which problems to enter into the laboratory is sometimes made by multiplying the number of hours required to work the problem by hand, by the number of times it will have to be re-solved, with the product having to be greater than 10 . . .

How to use punched cards in connection with chemical process control was the subject of a paper by Stevens & Brady (National Lead, St. Louis) . . . Sherman, of Texas Co., reported on the API Research Project 44, in which more than 100,000 individual property values of physical constants and thermodynamics have been stored on 36,000 punched cards—all available for computation.

LIQUID ENTRAINMENT contaminates products, shortens the life of equipment, is responsible for losses of valuable materials, and causes other processing trouble, according to Reynolds (Metal Textile Corp.) at H. E. O'Connell's (Ethyl Corp.) symposium. Seven factors to consider before buying any entrainment separator were described. . . .

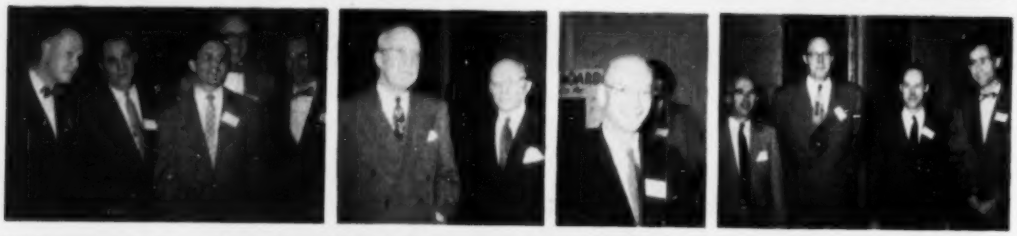
Entrainment with bubble-cap trays and Turbogrid trays was studied by Simkin, Strand & Olney (Shell Development). This should be of interest to distillation and absorption column designers. . . . Evaporator entrainment was studied by a Brookhaven group (Manowitz, Bretton & Horrigan) dealing with concentrating radioactive aqueous wastes. Bubble-cap and Raschig-ring-packed columns were ineffective for submicron particulates; fiberglass and metal wood were best. . . . How to design a wire mesh separator might be termed the outcome of studies by Carpenter & Othmer (Brooklyn Polytech.). Their experiments verified a mathematical prediction method which they say can be used for design . . . Practical considerations of wire mesh entrainment separators require attention to surface area, mechanical strength, economy, vapor velocity, efficiency, pressure drop and manner of installation—according to York (Otto H. York Co., Inc., East Orange, N. J.).

NEW CHEMICAL ENGINEERING HORIZONS was the keynote of W. C. Schroeder's (Bureau of Mines) Symposium on New Mineral Processing Techniques. . . .

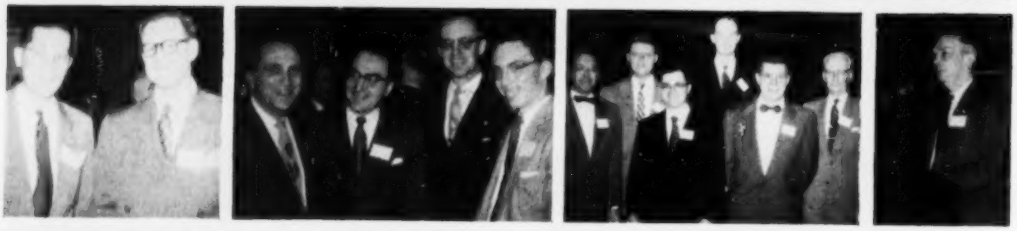
Titanium was produced last year at the rate of 2,241 tons/yr., contrasted to 50 tons/yr. in 1950, according to R. L. Powell (Titanium Metals Corp. of America), who described the process used . . . U. S. steel production could be set back to the 1898 rate, according to P. H. Royster (Mangaslag Inc., Washington, D. C.), if this country were forced through war to depend on the domestic supply of manganese, a critical additive in steel-making. A process for recovering that manganese, thrown away in steel-plant slags, is now in demonstration pilot-plant stage. If

W. C. Asbury; R. York; G. A. Schwabland & J. C. Moore; Mrs. C. G. Kirkbride; U. S. Rep. C. Hinshaw; H. F. Oswald & N. Murphy.

Fertilizer Symposium: E. C. Kapusta, G. L. Bridger, G. F. Sachsel, F. A. Retzke, S. J. Martenet, J. J. Dorsey, Jr., F. T. Nielsson, R. D. Filbert, Jr., & L. D. Yates; J. P. Eckberg, Jr.; W. L. Faith; C. J. Sindlinger & J. R. Bowman; W. D. Kavanaugh.

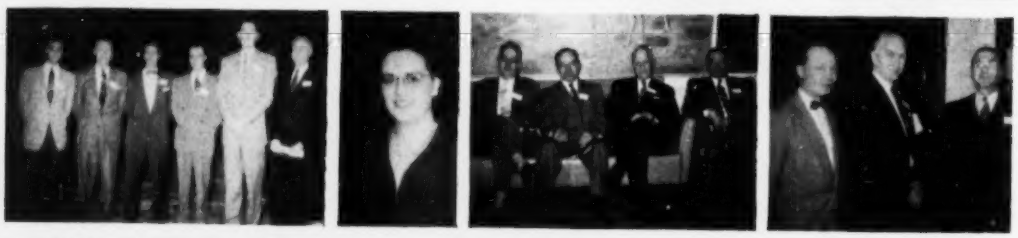


W. K. Davis, B. J. Cottrell, C. C. Neas, C. W. Angell & J. E. Vivian; R. D. Hoak & J. R. Minevitch; E. M. Schoenborn. Fundamentals Symposium: R. A. Kinckiner, W. C. Edmister, G. W. Holtzlander & J. W. Riggle.



H. E. Chaddock & R. W. Ewell; E. D. Holler, S. B. Row, H. H. Grice & T. H. Row. Liquid Entrainment Symposium: H. E. O'Connell, R. V. Harrigan, R. H. Overcashier, C. L. Carpenter, O. H. York & S. C. Reynolds; T. H. Chilton.

Mr. & Mrs. W. F. Twombly, Mrs. Clapp, J. S. Carey, E. J. Clapp, Sr., & Mrs. Carey; Mrs. C. G. Kirkbride & Mrs. A. K. Doolittle; J. A. Hufnagle & H. W. Zabel; H. B. Peterson.



Mixing Symposium: S. S. Weidenbaum, E. N. Martenson, K. L. Knox, R. B. Olney, J. Y. Oldshue & J. H. Rushton; R. Wheeler; R. P. Kite, C. W. Westphal (of Lima, Peru — believed to have come the greatest distance), H. F. Shattuck & A. G. Aitchison; F. R. Fisher, L. G. Coulthurst & J. C. Lawrence.

W. C. Edmister; C. J. Kentler, Mrs. Kentler, T. M. Jackson; J. S. Atwood, D. H. Killeffer & M. C. Molstad; J. T. Costigan & G. A. Randall; Commerce Under Secy. Walter Williams.

Gen. W. M. Creasy, N. L. Dickenson & A. S. Foust; R. Katzen, P. G. Foust & L. Maus; N. Parsley, F. E. Seery, Mrs. Seery & D. MacLean; G. L. Bridger.

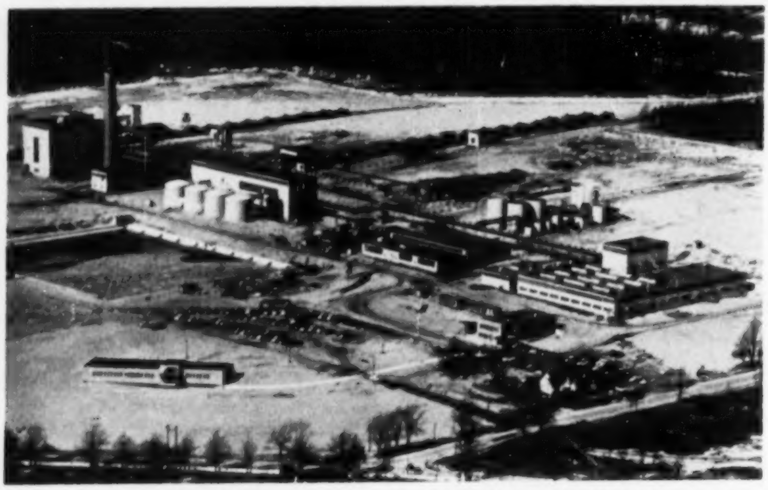
it succeeds, it may show the way towards national self-sufficiency. . . . New process for producing cobalt from cobaltite ore (Idaho) was reported by E. S. Roberts (Chemical Construction Corp., N. Y.) . . . First large-scale synthetic mica plant was described by R. A. Humphrey (Mycalex Corp. of America, Clifton, N. J.). Not only can natural isinglass now be duplicated in the plant—it is estimated that considerably more than 100 different micas with a variety of properties can be synthesized. . . . Zirconium is made today by a multistep batch process. Process developments made at the Bureau of Mines, Albany (Ore.) plant, which have doubled the plant capacity, were described by Gilbert & Morrison . . . Sodium metal has been available in quantity to industry only since 1952, according to Marshall Sittig (Ethyl Corp., N. Y.), who described its use as a reducing agent for the production of metals from their salts (titanium, zirconium and others), and for descaling . . . Powdered copper from scrap metal by ammonia-leaching followed by hydrogenation—a truly "chemical" process— . . . will be the basis for a new 5-ton/day plant described by Ryan (Whitaker Cable Corp., K.C., Mo.) and Van Hare (Chemical Construction Corp., N. Y.).

MIXING in full plant-scale operations took another major stride forward in J. Henry Rushton's (Illinois Inst. of Tech.) symposium . . . Considerable attention was shown other unit operations (heat transfer, liquid extraction) which are often employed along with mixing.

Oldshue and Gretton (Mixing Equipment Co.) presented data on heat transfer from helical coils in mixing vessels useful to the equipment designer . . . Overcashier, Kingsley, & Olney similarly covered liquid extraction . . . Progress towards standardization of mixer nomenclature and test procedures was reported by Oldshue, who is chairman of the Agitators' Subcommittee, A.I.Ch.E. Equipment Testing Procedures Committee, set up to help buyers and sellers test on a comparable basis . . . Solids mixing was dealt with in two papers—one from faraway India, the other dealing with a scientific analysis of solids mixing in a rotating drum. Mortenson (plant food div., Swift & Co., Hammond, Ind.) gave the paper by Maitra (Indian Inst. of Tech., Kharagpur, W. Bengal, India) . . . A contribution to the theoretical interpretation of solids-mixing phenomena was made by Weidenbaum & Bonilla (Columbia U., New York) . . . Another Columbia U. group —Hixson, Drew & Knox—also dealt

(Continued on page 76)

HOOKER OPENS CAUSTIC SODA-CHLORINE PLANT IN MICHIGAN



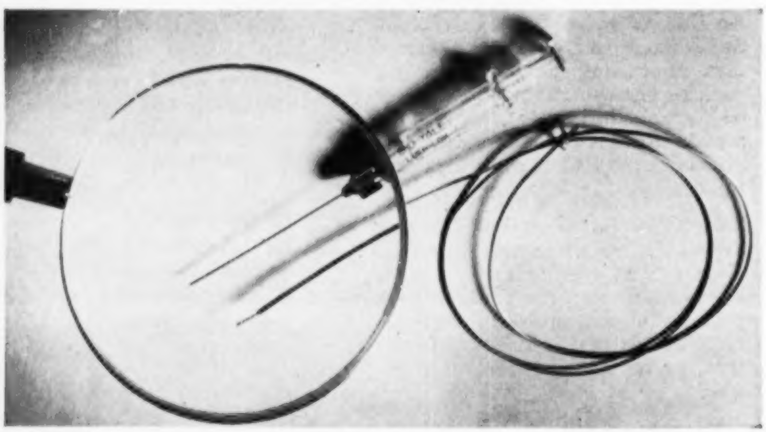
Operation of the new $12,000,000 caustic soda—chlorine plant of Hooker Electrochemical Co. at Montague, Mich., was started last month. The plant will supply 50% and 73% liquid caustic soda and liquid chlorine in tank cars and will ship caustic soda in bulk, as well as supply anhydrous hydrogen chloride by pipeline to Du Pont's projected neoprene installation.

THREE CHEMICAL FIRMS BUILD IN MICHIGAN

A new chemical industry community is rising at Montague, Mich., on White Lake, adjoining Lake Michigan, about 200 miles from Chicago. Du Pont plans a neoprene synthetic rubber plant on a 1,000-acre site adjoining the new Hooker Electrochemical Co. caustic soda—chlorine plant and the property on which Union Carbide and Carbon is expected to build an acetylene plant. The Hooker and Union Carbide plants will supply anhydrous hydrogen chloride and acetylene, the major raw materials for neoprene, to Du Pont by pipeline.

Selection of the site was due in part to the existence of a huge salt deposit, from which the chlorine will be made. Hooker has completed the caustic soda—chlorine plant at a cost of $12,000,000. The Du Pont plant is expected to be started in late 1954 and to be in partial operation by early 1956.

FINE, CORROSION-RESISTANT THERMOCOUPLE



Magnified view of new thermocouple developed at Argonne National Laboratory compared with standard hypodermic needle. The thermocouple has an outside diameter of 0.040 in., the hypodermic needle, about 0.025 in. The thermocouple, developed by Gerard Rauch of the metallurgy division of the laboratory, consists of a thin insulated constantan wire 0.015 in. in diam. inserted into an Inconel tube. The tube is drawn through a die on a draw bench to ensure that the wire is tightly gripped and sealed within it; then the wire and tubing are fused at one end. The thinness, flexibility, and ruggedness of the thermocouple, the laboratory stresses, enable it to be threaded through small, winding passageways into places that cannot be reached by conventional models. Developed for measuring temperature inside the fuel elements of operating nuclear reactors, the thermocouple, which is highly corrosion resistant, may be adapted to other processes. It has twice the electromotive force of conventional industrial models and has recorded temperatures up to 1,250° F. Although any length is possible, those produced at Argonne have been limited to 20 ft.

A.S.E.E. URGES PHYSICS AND NUCLEAR SCIENCE

Two summer institute symposia are being planned for 1954 by the American Society for Engineering Education and the National Science Foundation to implement the society's recommendation that modern physics, including nuclear science and solid state physics, become part of the engineering curriculum.

The working conference on nuclear physics will be held at Columbia University from April 21 to 23. Participation will be by invitation only, and the conference will determine the subject matter to be treated in an open conference to meet at Northwestern University from September 7 to 11. The conference at Northwestern will be open to physics and engineering teachers who register in advance. Information may be obtained from Professor Robert L. Young, Technological Institute, Northwestern University, Evanston, Ill.

The University of Illinois was the site of the working conference on solid state physics, which was held from March 8 to 10 to lay the groundwork for the open conference at Carnegie Institute of Technology, Pittsburgh, Pa., from June 21 to 25. Information about this conference may be obtained from John W. Graham, assistant dean, Carnegie Institute of Technology, Pittsburgh, Pa.

CHEMICAL SALES HIT RECORD FOR 1953

A 1953 sales record 10% above that for 1952 was announced for its member firms, representing about 90% of the chemical industry, by the Manufacturing Chemists' Association, Inc. The total amount was over 20 billion dollars and reflected, according to the association, the expenditure in 1952 of about 1.4 billion dollars for new plants and facilities. Investment in improvements in 1953 soared to 1.6 billion dollars and may indicate the sales trend for 1954.

Another record pointed to by M.C.A. is the higher profits achieved by the chemical industry, which netted approximately 14% before taxes, compared with about 9% each for twenty-three other categories of American industry.

NEW CELLOPHANE PLANT

Olin Industries, Inc., has announced plans for the erection of a cellophane plant at Kern, Ind. The new plant, to be designed and constructed by DuPont, will double the productive capacity of Olin cellophane. It will employ about 600 people.

(*Continued on page* 44)

NEWS

(Continued from page 42)

BEVATRON IS PUT INTO OPERATION

The Bevatron, the most powerful particle accelerator yet built, has gone into successful operation at the University of California, Berkeley, the Atomic Energy Commission announced last month. The machine has accelerated protons to an energy of 5 billion electron volts (b.e.v.), the highest energy ever achieved by an accelerator. Design energy is 6.25 billion electron volts.

All the components of the 9 million dollar machine (built with A.E.C. funds) were separately tested prior to assembly. Then the components were made to work together. The first major problem was to perfect the injection of protons into the Bevatron accelerating chamber by making two satellite accelerators work together to get protons up to high enough energy to be handled in the big machine. After injection was achieved, the physicists developed the giant magnet's control of the particles in the accelerating chamber. The protons were allowed to coast around the chamber while control was tested. Finally the oscillator, which boosts the protons to high energy, was turned on for acceleration to high energy. The first successful acceleration was to 20 million electron volts, and energy was built up gradually until 4.7 b.e.v. was reached. Physicists are working to push the machine to its design energy.

LAWRENCE OF ARABIA

جمعية المهندسين المصرية

دعوة لسماع محاضرة

يلقي المهندس الدكتور Laurence M. Bass.

محاضرة باللغة الإنجليزية عن :

Professional Development of Chemical Engineers

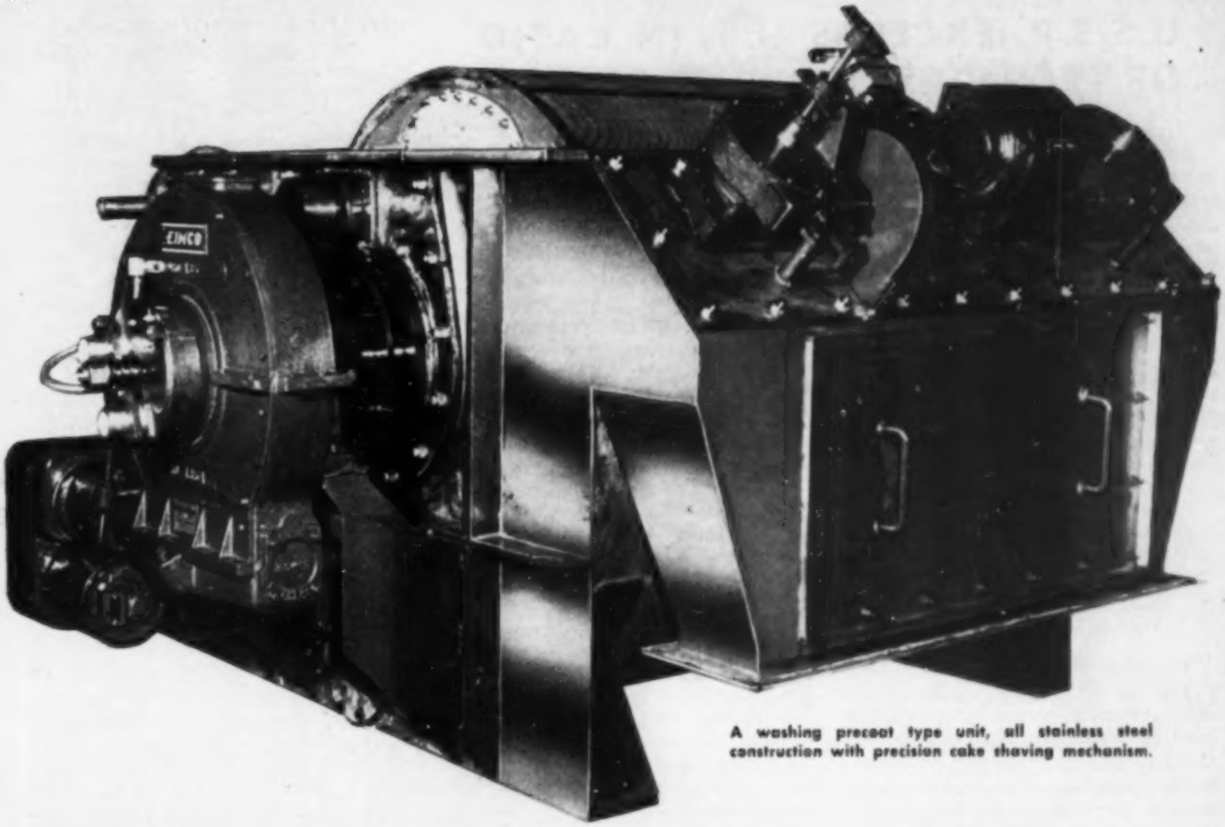
وذلك في الساعة الخامسة والنصف بعد ظهر يوم السبت الموافق ٦ مارس

سنة ١٩٥٤ بدار الجمعية .

ويسر الجمعية أن تتفضلوا بالحضور السكرتير العام

"As far as my absence of reading knowledge of Arabic is concerned, this invitation must be all right except for the misspelling of my name," writes Lawrence W. Bass, chairman of the Arthur D. Little technical staff in charge of studying potential industrial development of Egypt under provisions of the Point Four Agreement, who sent this proof that professional development of engineers is an international problem. Dr. Bass lectured on the subject in Cairo last month.

(Continued on page 46)



A washing precoat type unit, all stainless steel construction with precision cake shaving mechanism.

U.S.S.R. EXCEEDS U.S. IN RATIO OF TECHNICIANS TO ENGINEERS

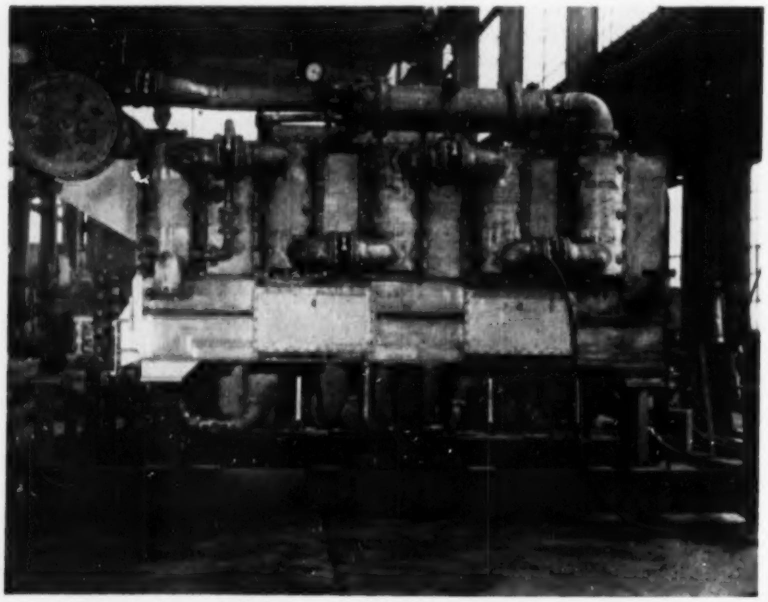
Russian awareness of the necessity for trained scientific and technical personnel is illustrated in a recent issue of the Engineering and Scientific Manpower Newsletter issued jointly by the Engineers Joint Council and the Scientific Manpower Commission. Statistics taken from a paper by M. H. Trytten presented at the E.M.C.-S.M.C. symposium "Utilization of Specialized Manpower Abroad" compare U. S. and U.S.S.R. figures for students and technical personnel. In the table below, 1951 figures are employed as a base.

Dr. Trytten adds that the Russian technical institute, or technicum, which students attend after elementary school, graduates about 350,000 students annually. In 1952 there were 3,500 of these institutes with about 1,200,000 students enrolled. "These schools," he says, "have three- or four-year courses. About fifty thousand of these graduates seem to be in fields related to engineering; [therefore] the number of technicians or semiprofessional engineers available to the Russian economy appears to be considerably larger than the number of professional engineers in the ratio of approximately two to one." He further adds that "even in the schools that closely approximate our secondary schools, about 24% of the curriculum is devoted to mathematics, physics, and chemistry . . . . Although we have no desire to regiment education at any level, one must wonder whether we are not entirely too casual in our emphasis upon the science and technology on which our security and economy depend."

	U.S.S.R.	U. S.
Secondary school enrollment	37,000,000	30,470,000
College enrollment	916,000	2,116,000
Ph.D. or equivalent degrees conferred	5,500	7,700
Engineers graduated (1953)	43,000	24,000
Engineers in the labor force	400,000	500,000
Scientists in the labor force	150,000	243,000

The importance of these figures is emphasized by Dr. Trytten, who points out that many American college students have no stated professional goals, but that "enrollments in Russian institutions, on the other hand, are more closely related to the needs of the Russian state for trained personnel for its activities . . .; therefore, the yield in trained professional personnel of the Russian system is greater in numbers than is our own for the same number of students enrolled."

NEW DISTILLATION UNIT DESIGNED FOR THE NAVY



A unit of a new flash-type distilling plant for producing fresh water from sea water, believed to be the largest of its type yet produced. Designed by Griscom-Russell Co. of Massillon, Ohio, and Bethlehem Steel Co., the unit will be tested at Bethlehem's Quincy yard and shipped to the Navy.

CHEMICAL ENGINEERS GET HIGHEST SALARIES

Chemical engineers graduating in January, 1954, from Illinois Institute of Technology, Chicago, Ill., topped all other engineers in the class by averaging \$394 monthly as a starting salary, an increase of almost \$70 a month over January, 1953. Civil engineering graduates averaged \$388 monthly, compared with \$353 for January, 1953; mechanicals received \$370 as against \$353 a year ago; electricals, \$367 as against \$345; and industrials, \$350, a decrease of \$6 from January, 1953.

The average starting salary for all engineering graduates of January, 1954, at the institute reached an all-time high of \$373 monthly, 9.3% more than for the previous January. Each man averaged 7.5 job interviews before leaving school.

OCCUPATIONAL ADVICE TESTED BY MILITARY

A six-state area to test the feasibility of establishing advisory committees on the classification of scientific, engineering, and other specialized personnel to consult with local selective service boards has been set up by the Selective Service System. "The increasing technical nature of many occupations may require," said Lewis B. Hershey, director, "that . . . the boards be provided, in appropriate cases, with expert advice on the basis of which they may make valid judgments with respect to the relative need for individual registrants in military or supporting civilian activities."

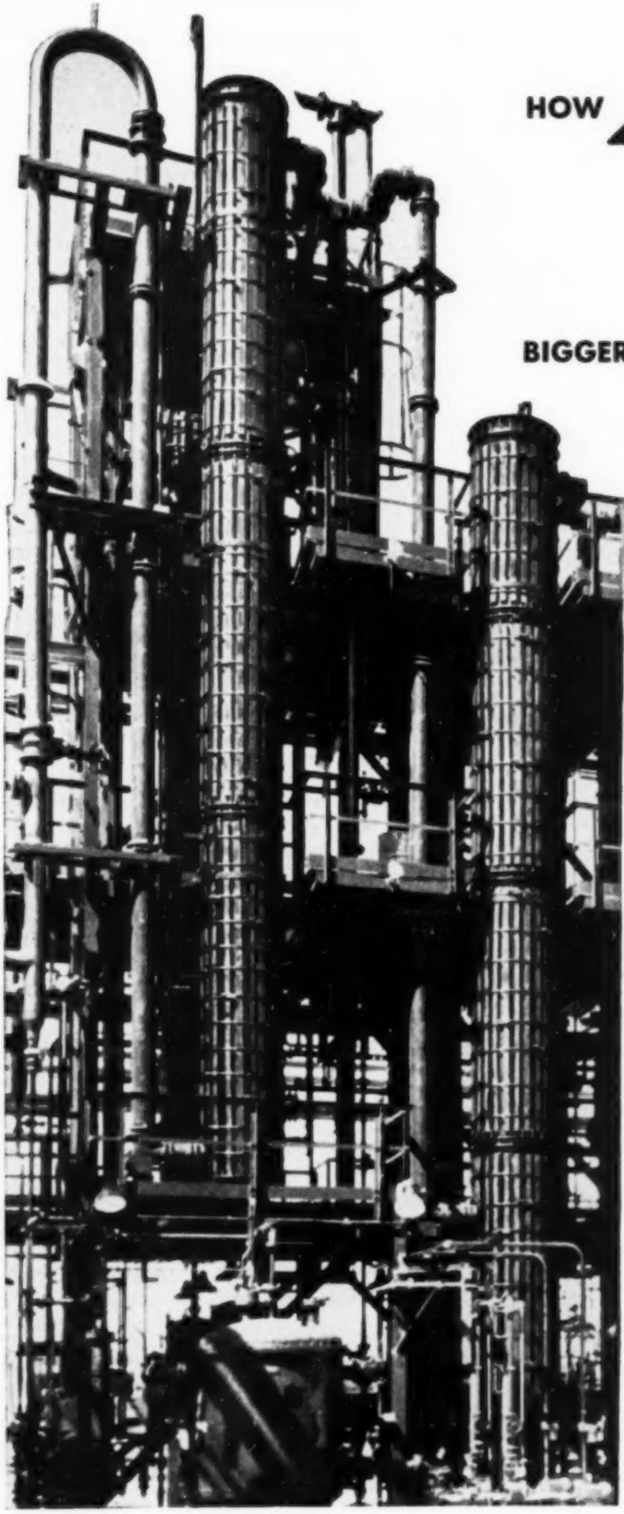
The six states in which the test is being made are Alabama, California, Michigan, New Jersey, New York, and Ohio.

WORLD PETROLEUM CONGRESS IN 1955

The Fourth World Petroleum Congress will be held in Rome from June 6 to 15, 1955, according to an announcement by E. V. Murphree, chairman of the permanent council of the organization and president of Standard Oil Development Co. More than 200 papers will be presented by leading industrial and university scientists from all over the world to about 4,000 representatives expected to attend the meeting.

Among the members of the U. S. National Committee are H. W. Field, Atlantic Refining Co.; H. G. Vesper, California Research Corp.; M. E. Spaght, Shell Oil Co.; W. M. Holaday, Socony-Vacuum Oil Co.; and J. K. Roberts, Standard Oil Co. (Indiana).

(*Continued on page* 48)



HOW HAVEG HELPS YOU BUILD

TRADE MARK REG. U. S. PAT. OFF.

TOWERS

BIGGER, BETTER, CORROSION-RESISTANT

This was a big, exacting job for an old Haveg customer, and a good example of Haveg's usefulness as a material and a process equipment manufacturer. The project engineers specified towers of Haveg to eliminate their major problems in the fight against corrosion.

FIRST, WHAT IS HAVEG?

Haveg is a plastic material sold in finished process equipment, or as a cement for construction of plastic equipment in the field. It is not paint or a coating. Made from acid-digested asbestos bonded with special corrosion-resistant resins, Haveg is usually molded and cured into its finished forms: Cylindrical and rectangular tanks and towers, pipe and fittings, valves and pumps, fume duct systems, heat exchangers. Haveg takes high sustained temperatures (over 265°F. with a wide margin of safety). It resists thermal shock, seldom requires insulation.

HAVEG CAN BE BIG

Because Haveg is a molded plastic with adequate physical strength for self-supporting equipment, large equipment can be made. Diameters from ½ inch to a maximum of 10 feet can be built up in sections. The towers illustrated were assembled three and four high, with standard metal flanged connections. Metal inserts for connecting studs can be embedded in Haveg at the time of molding. However, most pipe connections are molded into the wall ready to take any standard pipe.

HAVEG WIDENS YOUR DESIGN RANGE

If you were to make a model of your next tower installation you would mold in many desirable features not usually possible with standard construction materials: More outlets, improved trays and distributors. When you build with Haveg all this becomes possible and practical. Haveg is inexpensively and rapidly molded into the design, shape, form you need to do a better chemical handling job. Openings, special bottoms are built into your tower sections by skilled plastics molders. Should your plans or processes change, Haveg can be machined and altered by you, on the job. Accidental mechanical damage is easily repaired, using Haveg cement and maintaining full chemical resistance.

KNOW THE FULL STORY

Haveg has a proven service record in the toughest chemical services, resisting most acids, salts, chlorine, many solvents. There's much more to tell about Haveg and the way it can help you. A 64-page illustrated Bulletin F-6 is yours for the asking. Contains size and chemical resistance charts, design specifications. Write today. Also, talk to the Haveg sales engineer whose office and phone is listed. Remember, Haveg is a logical answer to your design problem in towers; in fact, on all process equipment that touches corrosives.

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*A subsidiary of Continental-Diamond Fibre Co.

THIS MONTH IN INDUSTRY

• Sinclair Refining Co. has contracted for a sulfur recovery unit to produce 30 tons of sulfur daily from hydrogen sulfide recovered from refinery gas streams at the Houston, Texas, refinery.

• Construction of a phthalic anhydride plant adjacent to its present Elizabeth, N. J., plant was announced recently by Reichhold Chemicals, Inc. Part of a $10,000,000 expansion program, the new plant, together with an expanded maleic anhydride plant, will increase the company's total annual production of phthalic to 80,000,000 lb. and of maleic to 10,000,000.

• The New Jersey Zinc Co. has announced purchase of the Gloucester City, N. J., titanium dioxide plant of American Cyanamid Co. The turnover will be made late in 1955.

• Plants in Canada have been announced by the Rohm & Haas Co., which is constructing one at Scarboro, and by Dow Chemical Co. of Canada, for which The Fluor Corp. of Canada is engineering and constructing an expansion of the ammonia plant at Sarnia.

• Establishment of the ElectroData Corp. as a wholly owned subsidiary of Consolidated Engineering Corp. at Pasadena, Calif., took place recently. The new company will continue the activities of Consolidated's Computer Division.

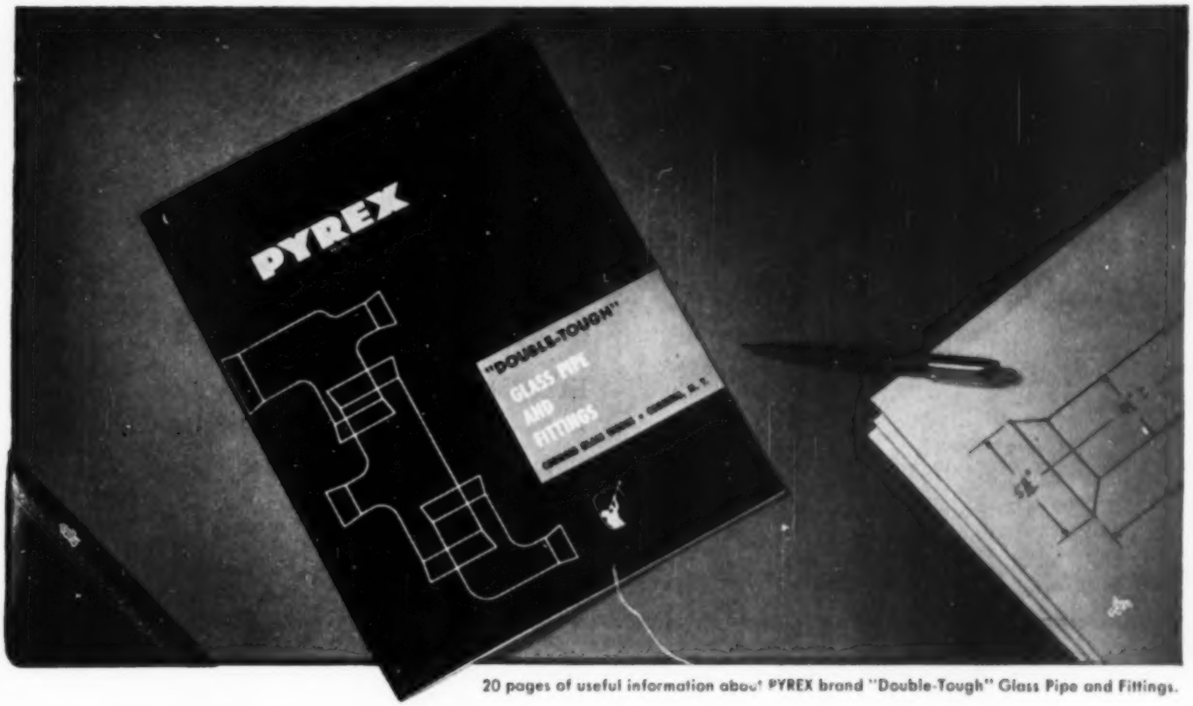
• An investment of about 1 million dollars has been made by The Visking Corp., Chicago, for a plant for polyethylene film extrusion to be located near Flemington, N. J. Operation will be started in August, 1954.

• Electrical controls will be produced from Roanoke County, Va., in 1957, according to an announcement by General Electric, whose Industry Control Dept. will be moved from the Schenectady works on completion of the new multi-million-dollar plant.

• The Unifining process for purification of petroleum distillates by means of a cobalt-molybdenum catalyst may now be secured under a single license from either the Union Oil Co. of California or Universal Oil Products Co. of Des Plaines, Ill.

• Realignment of sales and research groups in the Chemicals Dept. to form a special Food Industry Division has been announced by Atlas Powder Co., which has also announced plans for construction of two esterification plants at Memphis, Tenn., and Brantford, Ont.

(Continued on page 60)



20 pages of useful information about PYREX brand "Double-Tough" Glass Pipe and Fittings.

This new catalog describes the most practical means of fighting *pipeline corrosion and contamination*

The new PYREX brand "Double-Tough" Glass Pipe Catalog describes the basic properties that make PYREX pipe the solution to most acid-handling pipeline problems. It catalogs completely what's available in PYREX pipe and fittings.

Cost-reducing improvements

The new catalog lists for the first time two pipe joint improvements that contribute substantially to lower installation and maintenance costs—a new molded insert and a new snap-on gasket.

The molded insert reduces any tendency toward leaky joints. The snap-on gasket, made of Teflon, will stand up to the severest acid corrosion service.

Together, the new insert and gasket reduce the assembly of PYREX pipe joints to a one-man job. Friction holds the insert in place on the pipe ends and tough brass clips correctly position the gasket between the pipe ends while the joint is pulled up tight. Both are described on page 12 of the catalog.

You may find it convenient to have this new PYREX pipe catalog at hand. The distributor nearest you will be glad to send you a copy without further obligation on your part. If you do not know him, just fill out and mail the coupon direct to us at Corning.

Contents of new PYREX pipe catalog

- Performance
- Corrosion resistance
- Operating temperatures and pressures
- Physical characteristics
- How PYREX pipe is made
- Economy
- Cleaning
- Installation
- Pipe specifications
- Stock fittings
- Non-stock fittings
- Spacers for making length adjustments
- Adjustable joints
- Sink traps
- Stock valves
- Joints
- Flanges, gaskets, inserts
- Adapters for connecting with other materials
- Special fittings
- How to order

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Please send me a copy of the new PYREX brand "Double-Tough" Glass Pipe Catalog.

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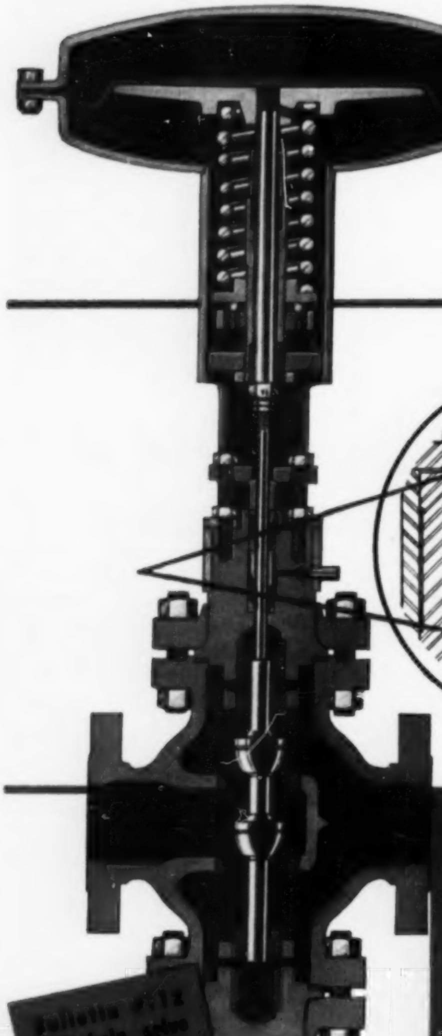
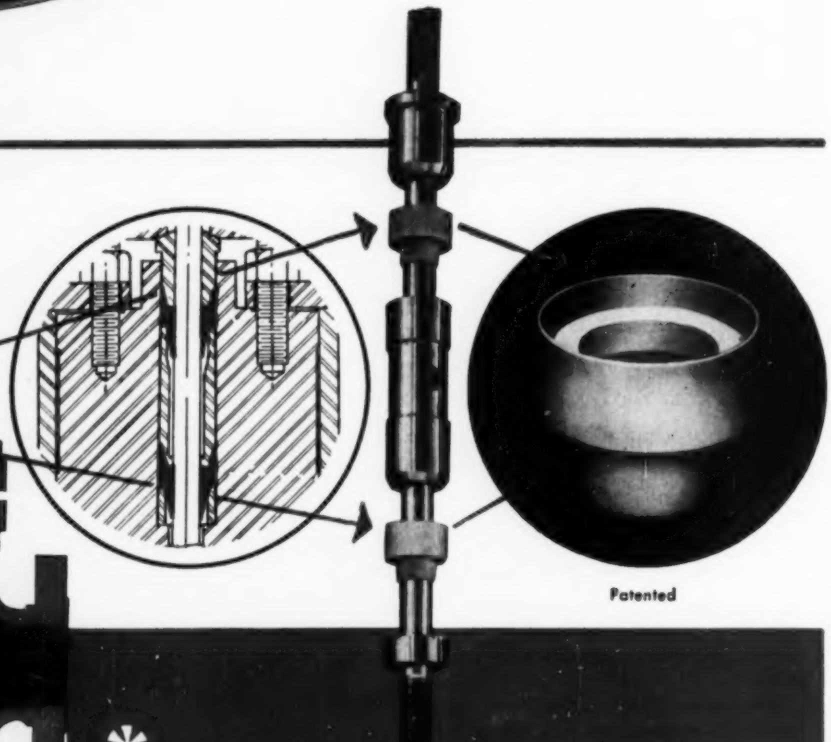
"Dahl-Seal"®*

AVAILABLE ONLY IN HAMMEL-DAHL CONTROL VALVES

ELIMINATES PACKING BOX
. . . . and its problems





Patented

* No more leakage, friction, periodic take-up adjustment, lubrication or replacements. The Dahl-Seal provides a frictionless, leak-proof Valve stem, regardless of static pressure in system.

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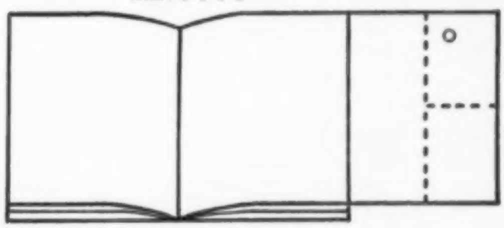

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5A
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7A
8A
9A
10L
11A
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13A
14L
15A
16A
17A

PRODUCTS

IFC **Gasholders**
Description of all-weather gasholders.
Wiggins Gasholder Div., General American Transportation Corp.

3R **Vibrox Packer**
Vibrating and rocking motion packs dry powdered, granular or flake materials.
B. F. Gump Co.

4A **Gate Valves**
Features cast iron wedge gate 18-8 Mo alloy trimmed, flanged ends. Applications in wood treating and pulp and paper processing.
Crane Co.

5A **Fluid Phthalic Plants**
Designed and erected. Also synthetic urea process.
The M. W. Kellogg Co.

6L **Heavy Duty Filter**
1,000 sq. ft. of filtering surface, 2,000 lb. filter cake, vertical plate filter.
Sparkler Mfg. Co.

7A **Porcelain Valves**
Description and cross-section shown. Bulletin gives complete description, characteristics, and specifications.
Lapp Insulator Co., Inc.

8A **Diatomite Powders**
Celite as an anti-caking agent in fertilizers, for fluffing up household cleaners, pigments in paint and paper, etc.
Johns-Manville

9A **Oxygen Plants**
Features scale model of 160 ton per day pure oxygen plant under construction.
Blaw-Knox Co., Chemical Plants Div.

10L **Process Piping**
Engineering guidance and manufacturing.
Badger Mfg. Co.

11A **Vertical Pumps**
For volatile fluids such as gasoline, diesel fuel, etc.
Johnston Pump Co.

12A **Yorkmesh Demisters**
Describes case study of entrainment elimination giving 31% capacity increase.
Otto H. York Co., Inc.

13A **Hydrogen Plant**
Plant illustrated produces hydrogen exceeding 99.8% in purity, continuously.
The Girdler Co.

14L **Sintered Glass Filters**
Featuring filter plates and filter discs.
Ace Glass, Inc.

15A **Petroleum and Chemical Plants**
Features petroleum refinery at Dunkirk, France, designed, engineered and constructed by Lummus.
The Lummus Co.

16A **Insulation**
Explains how company saves fuel, reduces maintenance on outdoor tanks with insulation.
Johns-Manville

17A **Feeders, Dryers**
Screw type concentrating feeders and centifugal dryers, for installation with continuous centrifugals.
Baker Perkins, Inc.

18A **Drying Problems**
Drying research laboratory.
C. G. Sargent's Sons Corp.

19A **Valves**
Automatic, manual or remote control. Also valve lubricants.
Rockwell Mfg. Co.

21A **Control of Process Heat**
Heat transfer medium maintains temperatures within a fraction of a degree. Used as a vapor heating medium in a closed system.
The Dow Chemical Co.

22A **Petroleum Caustic Soda for Refining**
Graphite anodes, electrodes, molds and specialties.
Great Lakes Carbon Corp., Electrode Div.

23A **Chemical Pumps**
Made of Ircamet—a high nickel-chromium-molybdenum alloy steel to provide resistance to acids and alkalis. Sizes from ¼ to 125 hp.
Ingersoll-Rand, Cameron Pump Div.

24L **Pumps**
Made in twelve standard alloys to pump corrosive solutions.
The Duriron Co., Inc.

25A **Crystallization Equipment**
Shop view of unit 50 ft. high and 11 ft. 3 in. in base diameter. Crystal appearance also shown.
Struthers Wells Corp.

26A **Vacuum Furnaces**
For melting and casting gas-free metals. Also for sintering, annealing and degassing.
F. J. Stokes Machine Co.

27A **Butadiene from Normal Butane**
One step dehydrogenation process is applicable also to the production of propene from propane, isobutene from isobutane, styrene from ethyl benzene, and methyl styrene from isopropyl benzene.
Houdry Process Corp.

28A **Measuring and Controlling Equipment**
Features control system for addition of caustic to phosphate flotation process.
Minneapolis-Honeywell Regulator Co.

30A **Steel Belt Coolers**
Features how ammonia and nitric acid react directly at 400 degrees F. to yield molten nitrate, which is cooled to solid form on Sandvik belts, broken up at take-off and then crushed.
Sandvik Steel Belt Conveyors, Div. of Sandvik Steel, Inc.

31A **Complex Fertilizer**
Complex fertilizer by a continuous chemical process will provide a complete integrated plant.
The Chemical & Industrial Corp.

32L **United States Gasket Products**
Features three new catalogs; gaskets and accessories, valve and pump packings, and expansion joints and flexible couplings.
United States Gasket Co.

33A **Rotary Disc Contactor**
For liquid-liquid counter-current extraction.
Turbo-Mixer Div., General American Transportation Corp.

Chemical Engineering Progress

Numbers followed by letters indicate advertisements, the number corresponding to the page carrying the ad. This is for ease in making an inquiry as you read the advertisements. Letters indicate position—L, left; R, right; T, top; B, bottom; A indicates a full page; IFC, IBC, and OBC are cover advertisements.

Be sure to give name, address, position, etc.

Remember, the numbers on the upper portion of the card bring you data on only the bulletins, equipment, services, and chemicals reported in these information insert pages. The lower portion of the card is for the advertised products, and is keyed not only to advertising pages, but also to the memory-tickling list under the heading Products.

34A **Metering Pumps**
To proportionally inject reagents, detergents, inhibitors, and additives.
Proportioners, Inc.

166A **Paint**
For protection from corrosive fumes and gases.
The U. S. Stoneware Co.

37A **Dryers**
Features experience in designing and building dryers.
Louisville Drying Machinery Unit, General American Transportation Corp.

41R **Swivel Fittings**
Manufactured for almost every type of service.
Emsco Mfg. Co.

43A **Pulsafeeder Pumps**
Piston-diaphragm controlled-volume chemical pump for fluids that are difficult to pump.
Lapp Insulator Co., Inc.

44L **Tantalum Equipment**
For most acid solutions and corrosive gases or vapors.
Fansteel Metallurgical Corp.

45A **Filtration Units**
Washing precoat unit, all stainless steel, cake shaving mechanism.
The Eimco Corp.

47A **Towers**
Haveg cylindrical and rectangular tanks and towers, pipe and fittings, valves and pumps, fume duct systems, heat exchangers.
Haveg Corp.

(Continued on back of this insert)

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31A	32L	33A	34A	166A	37A	41R	43A	44L
45A	47A	48L	49A	50A	59A	60L	61A	62L
63R	64L	64R	65R	66L	67R	68L	69R	71R
72L	72TR	72BR	73T	73B	74L	74R	75R	77R
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31A	32L	33A	34A	166A	37A	41R	43A	44L
45A	47A	48L	49A	50A	59A	60L	61A	62L
63R	64L	64R	65R	66L	67R	68L	69R	71R
72L	72TR	72BR	73T	73B	74L	74R	75R	77R
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PRODUCTS *(Continued)*

48L **Air Conditioning**
Exact moisture control for your comfort, your process, or for testing.
Niagara Blower Co.

49A **Glass Pipe**
Features pipe joint improvements, new molded insert, and a new snap-on gasket.
Corning Glass Works

50A **Control Valves**
Seal eliminates packing box, and is indicated to provide a frictionless, leak-proof valve stem, regardless of static pressure in system.
Hammel-Dahl Co.

59A **Blenders**
Features 150 cu. ft., 6600-lb. batch blender.
The Patterson-Kelley Co., Inc.

60L **Diaphragm Valves**
Saunders patent valves isolate working parts from flow. Manual or remote operators. Sizes range from ⅜ in. to 14 in.
Hills-McCanna Co.

61A **Conveying Systems**
Sealed casings insure dust-free, contamination-free movement of water treatment chemicals.
Stephens-Adamson Mfg. Co.

62L **Heat Exchangers**
Specialists in extended heat surface exclusively. Complete engineering service at the plant and in the field.
Aerofin Corp.

63R **Vapor Condensers**
Standard stainless steel vapor condensers and thermosyphon reboilers.
Doyle & Roth Mfg. Co., Inc.

64L **Pumps and Compressors**
Built-in aircheck valves. Pumps for boiler feeding, general power plant and industrial use. Catalog.
Pennsylvania Pump & Compressor Co.

64R **Books for Chemical Engineers**
Describes three recent titles: "Fresh Water from the Ocean," "Electrolytic Manganese and Its Alloys" and "The Evolution of Chemistry."
The Ronald Press Co.

65R **Knight-Ware Vessels**
Used in the recovery of bromine from brine. Acid proof throughout, except for hydrofluoric acid and hot caustics.
Maurice A. Knight

66L **High Alloy Castings**
In chrome iron, chrome nickel or nickel chrome. Features rings for jet engines
The Duraloy Co.

67R **Screening Material**
Wire cloth woven from all commercially used metals in sizes ranging from 4 in. (space cloth) to 400 mesh. 5,400 different combinations. Catalog.
Newark Wire Cloth Co.

68L **U. S. Syncrogear Motors**
Geared motor with solid shank pinion. 4 to 10,000 rev./min., ¼ to 30 hp.
U. S. Electrical Motors, Inc.

69R **Heat Exchangers**
Features Impervite heat exchangers installed in the production facilities of a large manufacturer of agricultural, industrial and pharmaceutical chemicals.
Falls Industries, Inc.

71R **Chlorination**
Slime control equipment designed for any need.
Wallace & Tiernan

72L **Filter Papers**
Manufacture of filter papers for laboratory and industry. Booklet.
The Eaton-Dikeman Co.

72TR **Explosion Proof Temperature Limit Controls**
Ranges from —300° F. to 1,800° F. For controls, safety-alarms, cut-outs.
Burling Instrument Co.

72BR **Process Engineering & Equipment Design**
Process engineers translate laboratory or pilot plant data into chemical plant, create equipment.
Foster D. Snell, Inc.

73T **Valves**
Plug valves for all soapy, fatty lines. Rubber-faced plugs resist gum-up.
DeZurik Shower Co.

73B **Retubing Service**
Repair, retube and rebuild any type of tubular equipment in the field or at plant. Also condensers, evaporators, heat exchangers, etc.
Condenser Service & Engineering Co., Inc.

74L **Sand Filter**
Compartmented filter bed and traveling backwash mechanism automatically cleans. Used for plant supply water or for waste water treating.
Hardinge Co., Inc.

74R **Vitreosil Crucibles, Dishes, Trays**
Immune to extreme chemical, thermal and electrical conditions. Bulletin.
The Thermal Syndicate Ltd.

75R **Swing Joints**
Ball bearing swing joints designed for loading or unloading lines handling fluids. Sizes 2 in., 2½ in., 3 in., 4 in., temperature range —40° F. to +2250° F.
Barco Mfg. Co.

77R **"Rubberhide" Linings**
Compounded from rubber or neoprene to provide resistance to specific corrosive agents.
Goodall Rubber Co.

78T **Proportioning Pumps**
7,500, 15,000 or 30,000 lb./sq.in. working pressure by the interchange of piston and cylinder assemblies. Bulletins.
American Instrument Co., Inc.

78B **Spraco Nozzles**
Full cone, flat spray and hollow cone spray nozzles. Catalog.
Spray Engineering Co.

79R **Heat Exchangers**
Also special equipment, pilot plant units and plant modernization programs.
Davis Engineering Corp.

PRODUCTS *(Continued)*

80L **Technical Molybdenum Trioxide**
The raw material for the production of all molybdenum compounds.
Climax Molybdenum Co.

81T **Flexible Couplings**
For smooth power transmission. Catalog and selector charts.
Lovejoy Flexible Coupling Co.

81B **Meters**
Xacto meters to measure liquids accurately and dependably.
Bowser, Inc.

82T **Skin Barrier Cream**
Indicated to offer protection against irritants and sensitizing agents encountered in industry.
Ayerst Laboratories

82B **Hydrostatic Gauges**
For pressure, vacuum, draft depth and absolute, barometric, and differential pressure. Bulletins.
Uehling Instrument Co.

83TL **Technical Data Books**
Condensed data for the student, engineer, technical worker and business man. Catalogs.
Lefax

83BL **Stainless Steel Products**
Varied line includes buckets, pipe fittings, valves, wood screws, balls, bolts, chain, faucets, floats, etc.
Schnitzer Alloy Products Co.

83R **Duct and Stack Systems**
In standard round shapes only at low prices through improved manufacturing methods.
The Chemical Corp.

84L **Density Gauges**
For automatic control tasks involving liquids, slurries, sludges, etc.
The Ohmart Corp.

85T **Bubble Caps**
Bulletin 21 lists 200 styles. Special caps designed.
The Pressed Steel Co.

85B **Furane Cement**
A mortar for corrosion-resistant masonry.
Delrac Corp.

87R **pH, Chlorine Tests**
Color comparators give pH, chlorine, phosphate or nitrate determinations.
W. A. Taylor and Co.

88L **Antifoam**
3 grams kill foam in 10 tons of asphalt or alkyd resin. Free sample.
Dow Corning Corp.

89A **Jet Vacuum Equipment**
Jets and condensers used for vacuum cooling, jet mixers, jet heaters, jet absorbers, fume scrubbers, thermocompressors, etc.
Croll-Reynolds Co., Inc.

IBC **Pressure Vessels**
Also absorbers, special piping, ester kettles, and condensers.
The Vulcan Copper & Supply Co.

OBC **Fluid Mixers**
Tells how to choose a fluid mixer. Catalogs.
Mixing Equipment Co., Inc.

BULLETINS

1 **Hydroseal Pump.** Built in eight standard sizes, capacities 10 to 12,000 gal./min. Allen-Sherman-Hoff Co. Bulletin shows diagrams, cutaway views, gives selection charts, other data. Used where process liquids contain abrasive materials.

2 **Filters.** Catalog from Ertel Engineering Corp. covers line of standard & sanitary filters, mixers, pumps.

3 **Line Blind Valves.** A 24-page manual on the proper method of installing line blind valves. Section devoted to trouble shooting for faulty-installation techniques, with corrective procedures. Hamer Oil Tool Co.

4 (4) **High Pressure Diaphragm-Motor Regulating Valves**
5 from Minneapolis-Honeywell Regulator Co. detailed in specification sheet 426. For wide band proportioned control. Globe bodies maximum 3,000 lb./sq.in. at 450° F.; angle bodies 6,000 lb./sq.in. at 450° F. (5) Automatic, dry feed, pH control systems. Data sheet describes complete system. Designed for use with dry chemical feeders.

6 **Rheinhutte Centrifugal Pumps.** Literature kit containing complete information, including schematic diagrams of pumps & valves, from Neumann & Welchman, sole U. S. representatives.

7 **Hydraulic Controller.** Entirely self-contained for automatic control of flow, pressure, proportioning & other variables. Askania Regulator Co. Bulletin shows application diagrams, gives specifications, other information.

8 **Desk Size Plastic Chart.** Showing port & stop arrangements of Nordstrom multiport valves desk-size plastic chart from Rockwell Mfg. Co.

9 **Corrosion Resistant Linings & Tile Tanks.** Brochure from Stebbins Engineering & Mfg. Co. on its complete service including design, installation, maintenance & repair to meet any combination of process operating conditions.

10 **Valves.** Triple-action quick-closing valves, by-pass check valves, gate valve line blind, horizontal check valves in the line of Greenwood valve div., Vernoon Tool Co., Ltd. Bulletin contains schematic drawings, construction & operating data, etc.

11 **Motor Controls.** Binder insert catalog from Allen-Bradley Co. on line of motor controls. Sections on d-c automatic controls; a-c manual starters, relays & contactors, accessories, control panels, etc.

12 **Stainless Tubing & Pipe.** Technical data card 160 gives complete corrosion test data on Babcock & Wilcox Co. stainless tubing & pipe. Comparative resistance of several stainless Croloys also listed.

14 **Demineralizers.** Mixed bed, two- & four-bed demineralizers described & illustrated in catalog. Sizes & capacities from 5 to 2,500 gal./hr. Dimensional & performance data on all models. Barnstead Still & Sterilizer Co.

15 **Forged Steel Valves.** Globe & angle valves with screwed or flanged ends designed for dry chlorine gas or liquid to 300° F. Provide maximum safety, high corrosion resistance, easy servicing, leakproof bonnet joint. Illustrated folder. Crane Co.

16 **Tubing.** Tubing of stainless steel, nickel & nickel alloy from J. Bishop & Co. Platinum Works available in sizes ranging from 1/32 in. O.D. (& wall thickness .003 in.) to 1 in. O.D. (& wall thicknesses not more than .083 in.). Illustrated folder.

17 Process Pumps. Bulletin from Economy Pumps, Inc. illustrates type R pumps. Gives specification tables, design features. Variety of materials.

18 Velofin Agitator. Gearless agitator adjustable to wide range of loads or viscosity conditions. Includes top- or side-entering types, also portable mixers for open tanks. Simple construction, easy maintenance. Folder from H. E. Serner Co.

19 Strain Gauges. Bulletin from Baldwin-Lima-Hamilton Corp. gives applications data, specifications for 105 types & sizes of gauges.

20 Magnetic Separators. Permanent magnetic separators for removal of tramp iron subject of catalog from Eriez Mfg. Co. Illustrated catalog gives cutaway drawings, tables, etc.

21 Transformers. A G. E. Buyer's Guide on instrument transformer (1954). A 95-page binder insert with sections on potential & current transformers, metering outfits, portable transformers.

22 Electric Mantles. Bulletin 4A from Glas-Col Apparatus Co., Inc. discusses safety, design considerations, various types of heating mantles. Also lists capacities & wattage.

23 Zinc Anodes. Report on use of zinc for cathodic protection from American Zinc Institute, Inc. Includes engineering data, also practical information concerning types of suitable applications, desirable anode forms & methods of application.

24 Flow Meters. Barton Instrument Corp. flow meters include patented rupture-proof differential pressure units. Illustrated folder discusses construction details, applications, etc.

25 Continuous Infrared Analyzers. Liston-Becker gas analyzers for industrial & laboratory use. Instruments are positive, nondispersion-type infrared analyzers sensitive in p.p.m. ranges. Provide continuous plant stream analysis of many gases.

26 Industrial Steam Traps. Bulletin from W. H. Nicholson & Co. Featured are steam traps in sizes ¼ to 2 in. for pressures from vacuum to 300 lb. Capacity tables & dimensions, recommended piping diagrams, etc. included.

27 Pressure-Leaf Filter. New type H horizontal filter catalog from Niagara Filters div., of American Machine and Metals, Inc. Illustrated, gives data, discusses economies of using pressure-leaf filters.

28 Porous Kel-F Filter Medium. Filtration medium said to be completely resistant to all strong acids, caustics, oxidizing agents & common organic solvents. Brochure. Porous Plastic Filter Co.

29 Process Filters. Advanced design model H & model V vertical leaf horizontal-leaf filters from Process Filters, Inc. Said to provide higher feed rates, eliminates cake erosion, give equally distributed internal feed, improved cake washing & recovery. Illustrated bulletins show cutaway views.

30 Food Technology. Booklet from Foster D. Snell, Inc. describes services available to food industries. Subjects considered are packaging, flavor evaluation, product development, off-flavors, spoilage & others.

31 Heat Exchangers. Describing & illustrating heat exchangers of various types, catalog from Whitlock Mfg. Co. Available in variety of materials in standard sizes & types, plus specially designed units. Tables, pressure ratings, other data.

32 Condensate Return Units. Standard & heavy-duty units designed for handling condensate from all types of steam-heating systems. Folder from Fairbanks, Morse & Co. gives selection data, specifications, etc.

33 Stainless Steel. S. Blickman, Inc., fabricators of stainless steel, has booklet on qualities desirable in selection of this material. Gives chemical composition of various types, general characteristics, suggestions for selection, other pertinent information.

34 Pilot-Scale Crushers. Designed with many features of larger units are small crushers from American Pulverizer Co. Compact simple design, reinforced housings, easily maintained & cleaned. Sizes 9 x 9 in. & 15 x 9 in., capacities 600 to 1,000 to 2,000 lb./hr. Detailed folder.

35 Light-Wall Pipe. Speedline corrosion-resistant fittings and lightwall pipe are subjects of folder from Horace T. Potts Co. Make possible faster, easier installations at lower cost. Lighter weight 30 to 50% of schedules 5 & 10 facilities handling & assembly.

36 Centriseal Pump. Acid pumps of corrosion-resistant alloys. All parts interchangeable with antifriction bearing Hydroseal pumps. Brochure from Allen-Sherman-Hoff Co.

37 Mills & Kneaders. From J. M. Lehmann Co., Inc. literature kit containing folders on each item in line. Includes soap machinery, roll mills, etc. All pertinent data, plus schematic drawings, features.

38 Gravitometers. Various types for recording under all actual field conditions, & for use with all types of liquids. Working pressures to 600 lb./sq.in. Illustrated folder from American Recording Chart Co.

39 Swivel Joints. Bulletin from Barco Mfg. Co. titled "Self-Aligning Swivel Joints for Piping," covers variety of types of movable joints for use in process or service piping.

40 Motor Frame Selection Chart. Two-color wall chart shows new NEMA standard dimensions of Westinghouse Electric Co. Life-Line motors & controls in comparison with old.

41 Pressure Switches & Valves. Valves for manual control of vacuum or pressure to 6,000 lb./sq.in. illustrated & explained in catalog from Barkdale Valves.

42 Neoprene Notebook. Published by Du Pont, Neoprene Notebook containing facts about neoprene for the engineer. Deals with The Language of Rubber, Pt. IV in this issue. Discusses permanent set, stress, relaxation, other subjects.

43 Mixing Equipment. Said to operate 2 to 20 times faster than conventional mixers are Cowles Co., Inc. ultrafast dissolvers. Models with hydraulic lift; also tank type. Specifications, diagrams, variations available, all listed.

44 Small Capacity Pumps. Catalog from Milton Roy Co. featuring miniPump controlled volume pumps. Provide accurate metering of minute quantities of clear liquids. Meter at predetermined constant rate, or automatically controlled varying rate in range of 3 to 3,200 ml./hr. against pressures to 1,000 lb./sq.in.

EQUIPMENT

50 Smoke Photometer. Indicating & recording. Features improved optical system, adjustable range, logarithmic amplifier. Used in control of air pollution. Folder from Phoenix Precision Instrument Co.

51 **Horizontal Mixers.** Complete new line of horizontal mixers in capacities 3½ to 500 cu.ft. by Young Machinery Co. Illustrated folder includes schematic drawing, lists applications & construction features.

52 **Heat Exchangers.** Fluor Fin-Fan air-cooled heat exchangers for use in areas where water-nonevaporative cooling is sufficient. Illustrated bulletin from Fluor Corp., Ltd.

53 **Kel-F Tower Packing.** Raschig rings & perforated discs for packing support. United States Gasket Co.

54 **Synthetic Resin Pilot Plant.** Developed & made available in standard form from Brighton Copper Works, Inc., synthetic resin pilot plant available for other organic reactions as well. Made of type 316 stainless steel, has a 10-gal.-capacity reaction kettle.

55 **Syphon Elbow & Assembly Plate.** Two new products from Johnson Corp. reduce maintenance time in insertion & removal of mechanical syphon pipes in rotating rolls or drums.

56 **Fluorimeter.** Advanced design fluorimeter eliminates need for cooling systems & optical meters for laboratory or plant use. Jarrell-Ash Co.

57 **Swagelok Tube Fittings.** Tygon plastic tubing joined to Swagelok tube fittings & new Swagelok insert. Resistant. Sizes from 3/16 in. O.D. Crawford Fitting Co.

58 **Channel Pipe.** Chemi-Drain channel pipe developed by Dow Chemical Co. for its own use now being produced by Logan Clay Products Co. Made of vitrified clay, it is unaffected by all corrosive chemical fluids except hydrofluoric acid. For gutters & drains.

59 **Industrial Tapes.** Polyken industrial tapes in either black or aluminum gray have high corrosion & bacteria resistance, good conformability. Protect exterior of pipes & below ground. May be applied by hand or machine at 20 to 30 ft./min. Bulletin. Bauer & Black, div. of Kendall Co.

60 **Turbine-Type Pump.** Folder from Fairbanks, Morse & Co. on turbine-type pump. Capacities 179 gal./min., heads 350 ft., 1750 rev./min. Motor sizes ¼ to 10 h.p. Folder.

61 **Filter Plates.** Multi-Plates newly designed for plate & frame filter presses are lighter to handle, easier to clean & maintain. Withstand pressures to 600 lb./sq.in. Suitable for clarifying delicate chemicals, pharmaceuticals, beverages. Multi-Metal Wire Cloth Co., Inc.

62 **Ball-Bearing Units.** Rubber mounted ball-bearing units new by Stephens-Adamson Mfg. Co. Six shaft sizes ranging from ½ to 1 in. Illustrated folder gives specifications.

63 **Testing Instruments.** Miscellaneous laboratory equipment for testing, measuring & experimental work by James G. Biddle Co. Illustrated bulletin.

64 **Care of Platinum Dishes.** J. Bishop & Co. Notes on the Care and Use of Platinum Crucibles & Dishes" covers in detail all phases in the handling of platinum receptacles.

65 **Heavy-Duty Valves.** For ammonia & other hard-to-hold fluids, Crane Co. 300 lb. heavy-duty all-iron valves. Types are globe, angle, expansion, & check. Illustrated leaflet.

66 **Disintegrators.** Announced by Rietz Mfg. Co. disintegrator with swing-door body design, providing waterproof & dust-tight unit for processing liquids or finely divided solids. Permits easy access to interior.

67 **Airlock Feeder.** Heavy-duty rotary airlock feeder with 12 in. diam. inlet & discharge, developed by Prater Pulverized Co. for handling finely ground or granular abrasive substances including clay, silica, alumina & sewage.

68 **Recording Spectrophotometer.** General Electric Co. redesigned unit for industrial use in controlling color of paints, dyes, glass, textiles, other materials. Eliminates personal judgment factor.

69 **Porous Stainless Steel Filters.** Micro Metallic Corp. filters with areas to 720 sq.ft. & cake-space capacity to 35 cu.ft. High temperature resistance. Compact design, may be steam jacketed, easily cleaned.

70 **Nuclear Radiation.** A method for measuring & controlling variables using nuclear radiation without insertion of primary element in process stream discussed in data sheet from Minneapolis-Honeywell Regulator Co. Used with Brown electrometer & null-balance-type measuring circuit.

71 **Cellulose Acetate Proportioning System.** Remote control system for proportioning ground cellulose acetate & plasticizer described in technical reference sheet from Richardson Scale Co. Diagrammatic drawings illustrate each step in process.

72 **Stainless Steel Selector.** Physical or mechanical properties, room or elevated temperatures for any grade stainless easily found with new Crucible Steel Co. of America selector.

73 **Vibrating Feeder.** Vibrating mechanical feeder for continuous solids feeding. Wide operating range of 0.1 to 20 cu. ft. of product/min. Data sheet. Richardson Scale Co.

74 **Piping Blind.** Announced by Rockwell Mfg. C. line blind to increase safety & simplicity of mechanical blinding operations in fluid product piping-transfer systems. Obviates necessity for precise piping alignment. Tamper-proof locking device & simple one-wheel operation.

75 **Bantam Gauge.** For measuring draft, pressure, vacuum, or differential draft. Republic Flow Meters Co. Ideal for use on compact console & graphic panels. Pressure ranges as low as 0.6 in. & high as 40 in. of water.

76 **Silicone Products.** Dow Corning Corp. reference guide lists fifteen new items ranging from adhesives to molding compounds. New applications details.

77 **Kel-F Diaphragm.** Tough enough to withstand pressures to 3,000 lb./sq.in. Paper-thin diaphragm sensitive enough to flex with minute pressure variations. Chemically inert. M. W. Kellogg Co.

78 **Airchek Valves.** For service to 500 lb./sq.in gauge. Installed in discharge line of air or gas compressors. Pennsylvania Pump and Compressor Co.

79 **Packaged Air Conditioning.** Three types of packaged air conditioning & refrigeration units offered by Acme Industries, Inc. Heat pump comes in six models that deliver 26,000 to 252,000 B.t.u./hr.

80 **Shuntflo Meters.** Builders-Providence, Inc. in conjunction with C. E. Squires Co. has developed an engineered equipment package for measurement of steam under variety of load conditions.

81 **Bin Vibrator.** Brochure from Cleveland Vibrator Co. introducing electric vibrator for use with bins, hoppers, chutes, screens, drums, etc. Handles any free-flowing

material. Frequency of 3,600 impulses/min. equals 60 cycles/sec.

82 **Stainless Solenoid Valve.** Corrosion-resistant open-closed valve in 1/8- & 1/4-in. pipe sizes announced by Aktomatic Valve Co. Bodies 303 stainless, solenoid armature 416 stainless. Pressures 5,000 lb./sq.in. to 150° F. maximum; 2,500 lb./sq.in. to 400° F. maximum.

83 **Electronic Temperature Controller.** Series 97 electronic temperature controller by Fielden instrument div., Robertshaw-Fulton Controls Co. now available. For wide temperature ranges. Operates on principle of change resistance of wire-wound sensing element with changes in temperature.

84 **Fire Extinguisher.** A 2-qt. capacity stored air pressure vaporizing-liquid fire extinguisher introduced by Pyrene Mfg. Co. Combination carrying handle & squeeze-type operating valve, center balanced for easy manipulation.

85 **Vapor Compression Still.** Bulletin from Badger Mfg. Co. on still for producing pure pyrogen-free water of laboratory purity in production quantities. Discusses operating principle, economics, etc.

86 **Heat Transfer Equipment.** Bulletin on industrial heat exchangers tailored to individual requirements and available in wide range of alloys, from Industrial Filter & Pump Mfg. Co.

87 **Teflon V-Ring.** Reid Enterprises announce Teflon Super-Thin V-ring. Said to revolutionize packing methods & give better seal. Smaller, lighter units made possible by reduction of packing gland length & diameter. For use at temperatures —150 to +550.

88 **Dall Flow Tube.** Known as Dall flow tube new device from Builders-Providence, Inc. For use with gases & liquids carrying no settleable solids. Meehanite iron body, bronze liner. Minimum maintenance because of unobstructed flow path.

89 **Pilot Plant.** Now available to the chemical industry all-purpose pilot plant for small batch polymerization, esterification & other production. Temperature control 350 to 600° F. Other systems for range 50 to 700° F. Leaflet gives further details. Process Plants Engineering Co.

90 **Cooling Tower.** A 15-ton capacity cooling tower announced by Acme Industries, Inc. Five other sizes from 3 to 15 tons. Can conserve 95% of water used without tower. Brochure gives dimensions, weights, pump & fan characteristics.

91 **Solenoid 4-Way Valves.** Leaflet covering line of 3/4 in. solenoid controlled, pilot operated 4-way valves. Valves operate over range from 100 to 5,000 lb./sq.in. Three basic types available. Pantex Mfg. Corp.

CHEMICALS

100 **Silica Gel.** Developed by Davison Chemical Corp. PA-400 a high efficiency refrigerant desiccant. Preattrited to provide nondusting qualities. Particle size 8 to 20 mesh. Density 49 lb./cu.ft.

101 **Catalyst Carrier Materials.** Literature kit from Carborundum Co. on Catalyst Carrier Materials. Discusses background, new products, shape & size of carrier types, physical properties. Other data given.

102 (102) **Salicylamide.** Technical bulletin O-112 from Mon-
103 santo Chemical Co. on salicylamide. Includes properties & specifications, clinical experience, suggested applications. (103) Di-isodecyl phthalate low volatile plasticizer for polyvinyl chloride. Clear, oily liquid similar to di-2-ethylhexyl phthalate. Bulletin.

104 **Formula 67 Coating.** Announced by Babbitt Steam Specialty Co. formula 67, a protective coating for use on metal, wood, glass, brick, other masonry. Acid-proof & rust resistant, water, alkali & grease proof.

105 **Ethyl Alcohol.** Technical data sheet on ethyl alcohol—pure, denatured, proprietary solvents. Includes general & government regulations, specifications, grades & types, etc. Commercial Solvents Corp.

106 **Fatty Acids.** Emery Industries Inc. technical bulletin on fatty acids structurally modified to obtain combination of physical & performance properties not available in conventional fatty acids. Applications, availability, physical properties listed.

107 **Delrac Coating.** Permanent transparent coating which seals & waterproofs concrete, mortar, brick, steel & wood & applicable both as primer & finish coat. Delrac Corp.

108 **Butylene Oxide.** Now available on a commercial scale from Dow Chemical Co. synthetic butylene oxide straight chain isomers. Composed mainly of 1,2-butylene oxide with less than 1% isobutylene oxide. Very reactive in polymerization to produce polybutoxy-type compounds.

109 **Anti-Seize Compound.** High temperature thread compound protection against welding action of threaded connections subjected to high heats. Known as Thred-Gard, it is said to eliminate seizing & galling at temperatures to 1200° F. Crane Packing Co.

110 **Silica Sol.** Two products added to line of Philadelphia Quartz Co. Anhydrous sodium metasilicate & sodium orthosilicate, known as Metso Anhydrous & Metso 200. Illustrated data sheets give all pertinent information.

111 **Acid-Proof Coatings.** Duro-Kote & Duro-Kote No. 57 give vinyl & butadiene styrene acid-proof resin protection. Useful in corrosive applications. Brochure lists application, colors, composition.

112 **Sulfonic Acids & Sulfonates.** Bulletin from Hydrocarbon Chemicals, Inc. lists composition of all products in line, also appearance & price.

114 (114) **Ketones.** A 45-page booklet from Carbide and
115 Carbon Chemicals Co. Sections on physical properties, specifications, test methods, bibliography, other chemicals available. (115) Booklet on physical properties of synthetic organic chemicals. Presents data on more than 330 products & features 36 new chemicals.

116 **Polyester Resins.** (116) Illustrated brochure on Marco
117 polyester resins. General information plus list of properties, production techniques, applications. (117) Loose-leaf binder of technical bulletins on this material used for laminating, casting, coating, impregnating & molding. Celanese Corporation of America.

118 **Molding Plastics.** Illustrated booklet from Bakelite Co. on five types of phenolic molding plastics. Includes property table listing value of each type of phenolic when subjected to mechanical, electrical & other tests.

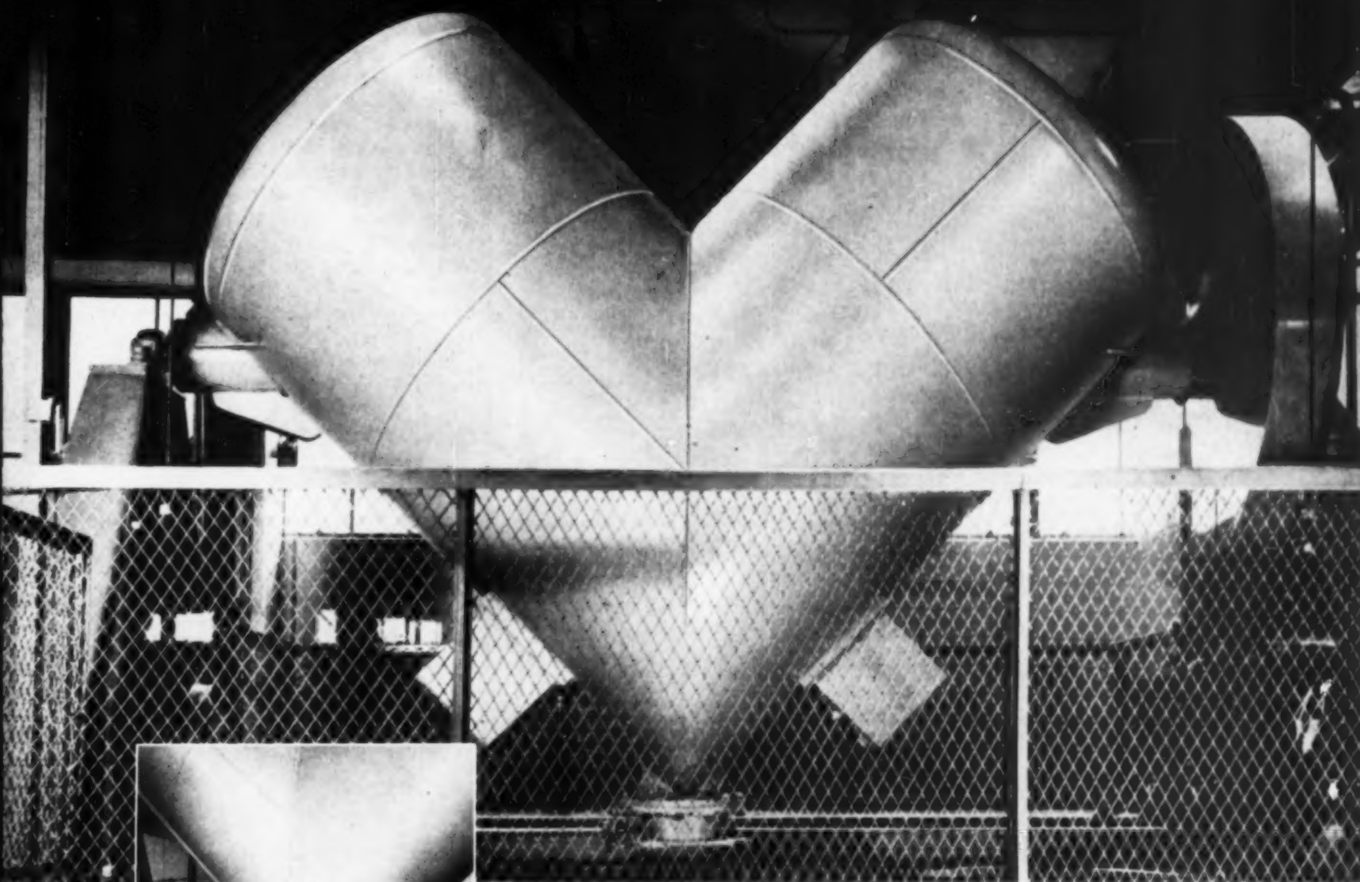
119 **Oils, Waxes & Greases.** Developed especially for high vacuum work Apiezon oils, waxes & greases from James G. Biddle Co. Low vapor pressure at room temperatures. Folder lists each type, also provides chart giving detailed data.

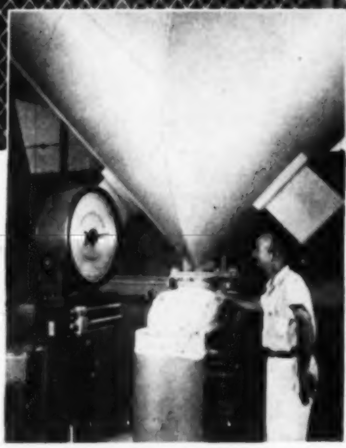
120 **Anhydrous Ammonia.** Data sheet on anhydrous ammonia lists specifications, physical properties, uses, toxicity, handling, etc. Commercial Solvents Corp.

ROCHE

HOFFMANN-LA ROCHE, INC.

blends a 3-ton dose of vitamins





Shown is ease of discharge of p-k blender.

150 cubic ft. p-k blender of stainless steel-clad construction is charged through opening in floor above.

Hoffmann-LaRoche, Inc., Nutley, N. J., leading pharmaceutical manufacturers, find blending a three-ton dose of vitamins in one batch an easy matter with a p-k twin shell dry blender.

And, at the same time, the patented p-k blender provides perfect dispersion of the ingredients, as uniformly as a druggist compounds a single prescription.

The 150 cubic foot p-k blender shown here is at work every day in the modern Hoffmann-LaRoche plant at Nutley, N. J. Five different particle sizes are perfectly blended in 6600-lb. batches in this p-k blender. Clinical cleaning is easy, because of the wide openings of the p-k blender.

If your blending needs a shot in the arm, write today for complete information on sizes and capacities.

the **Patterson-Kelley Co.,** inc.

1740 Lackawanna Avenue, East Stroudsburg, Penna.

101 Park Avenue, New York 17 • Railway Exchange Building, Chicago 4 • 1700 Walnut Street, Philadelphia 3 • 96-A Huntington Avenue, Boston 16 • and other principal cities.

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NEWS

(*Continued from page 48*)

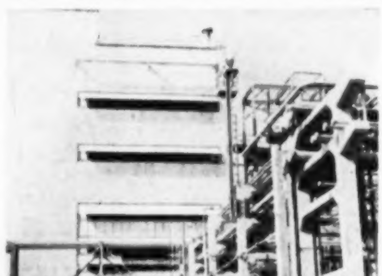
REWORKING OIL FIELDS YIELDS HIGH RETURNS

So-called depleted oil fields can be made to yield enough to increase by 75% the proven oil reserves of 35 billion barrels, according to the Reciprocating Pump Division of the Worthington Corp., which has recently made a spot survey of secondary oil recovery activities in the United States. Oil clinging to sand deposits can be recovered by water flooding through the use of specially designed high-pressure pumps, from petroleum fields once considered completely worked. Estimates of the amount of oil still underground in such fields range, according to Alvin Welsh, manager of the Worthington division, from 7 billion barrels (the opinion of the Interstate Oil Compact Commission), to 100 billion barrels (considered a fair figure by the Texas Railroad Commission).

NEW PROCESS FOR OIL REFINING DEVELOPED

A new process for extracting mercaptans from petroleum products has been developed at the Magnolia Petroleum Co., Beaumont, Tex., by C. A. Duval and V. A. Kalichevsky. Applicable to a, variety of systems involving alkali metal hydroxides, water, and organic substances, the process utilizes the two immiscible layers formed when optimum concentration for the separation is reached; consequently the name Dualayer has been applied.

SHELL CHEMICAL EPON RESIN PLANT



Completion of its epoxy resin plant at Houston, Tex., has been announced by Shell Chemical Corp. The plant will triple the company's production of Epon resins. Another unit of this new expansion is the bis-phenol-A plant, which manufactures all of this component used in the Epon resins.

(*Continued on page 62*)

NEWS

(Continued from page 60)

PROFESSIONAL ENGINEERS PRESENT SURVEY

"How to Attract and Hold Engineering Talent" is the title of a survey of 200 executives and 1,300 engineers by the Professional Engineers Conference Board for Inquiry in cooperation with the National Society of Professional Engineers. The fields covered included manufacturing, from which 45% of the replies came, construction, heavy industry, public utilities, government service, teaching, and research. The plants of employers and employees surveyed ranged from 47% with more than 1,000 workers, through 20% with 200 to 1,000 employees, to 33% with fewer than 200 employees.

Conclusions indicated that (1) industry could profitably devote more time to college programs, even teaching short practical courses in engineering; (2) the most desirable candidates were attracted by variety of job assignments, security, and opportunity for further training and advancement; (3) engineers seek primarily security and an opportunity for advancement, with professional recognition and a sense of personal achievement close seconds; company prestige and benefits also work toward keeping employees; (4) an improvement in communication between management and engineers is necessary for employee security; (5) engineers should be encouraged to participate in professional and community activities both for the sake of the man himself and for the benefit to the company's public relations; (6) interest in unions for engineers, although not widespread, has increased in recent years, and the survey stated that "the idea of encouraging nonbargaining, intraplant organizations for engineers also might be explored as a potentially beneficial move, not only from the standpoint of giving the engineers a vehicle of expression and a center for the interchange of ideas but also as a valuable channel of communication. It is very apparent from the survey results that a large number of engineers employed in industry now feel isolated and remote from management, and that the need for a thorough overhauling of company communications policies is indicated for most plants."

The survey may be obtained from the Professional Engineers Conference Board for Industry, 1121 Fifteenth Street N.W., Washington 5, D. C., for two dollars a copy.

DU PONT OPENS LAB FOR INDUSTRIAL HEALTH

A new laboratory for expanded research in industrial hygiene was dedicated by the Du Pont Co. near Newark, Del., last month. Built at a cost of $2,000,000, the structure will house the Haskell Laboratory for Toxicology and Industrial Medicine, which has a staff of 50 investigating the toxicity of chemicals made or used by the company and such health-maintenance problems as the causes and effects of fatigue, basic factors that make clothing comfortable, and methods for the early determination of abnormal heart conditions.

Originally established for testing products to eliminate potential hazards to employees and customers, the laboratory in its new location will continue this research to reveal the very early physiological changes caused by the actions of chemical compounds so that adequate preventive measures may be set up in company plants.

Unique installations in the laboratory are two all-weather rooms, in which scientists maintain temperatures ranging from −20° to 200° F. and wind velocities up to 20 miles/hr.

NEW RUBBER CHEMICAL ACCELERATOR OFFERED

A new rubber chemical has been developed by American Cyanamid Co. for increased protection against processing scorch in rubber compounds. NOBS Special Accelerator, which is *n*-oxydiethylene benzothiazole-2-sulfonamide, has been designed for use with high *p*H reinforcing blacks; it, according to the company, extends the safe processing period of scorchy stocks as much as 10 min. to allow mold flow in the first few minutes of the cure cycle and reduce surface defects and flow cracks.

SOLIDS HANDLING TO BE TOPIC OF I.S.A.

Problems in the storage and transportation of gases, liquids, solids, and fluidized solids, with emphasis on solids and fluidized solids, will be covered in a symposium on materials-handling instrumentation sponsored by the A.I.Ch.E. and the I.S.A. as a part of the I.S.A. conference to be held in Philadelphia in September. Persons interested in submitting papers on this subject should write to S. D. Ross, chairman of the symposium, at Minneapolis-Honeywell Regulator Co., Wayne and Windrim Avenues, Philadelphia 44, Pa.

(*Continued on page* 64)

OHIO SYMPOSIUM

The annual one-day Ohio symposium under the auspices of the Cleveland Section will be held April 23 at the Hotel Carter in Cleveland. Participating this year in "Advances in Chemical Engineering" will be all the Ohio sections of A.I.Ch.E. and, in addition, sections from Pittsburgh, Buffalo, and Detroit.

The technical program is as follows:

Morning Session

A. J. TELLER, Presiding

GOLD ROOM

9:45—DEWATERING OF THERMOPLASTIC RESINS BY SYNERESIS by P. M. Lindstet, Goodyear Tire & Rubber Co.

10:20—SEPARATION BY SELECTIVE ADSORPTION by G. Karnofsky, Blaw-Knox Co.

10:55—DESIGN AND OPERATION OF LIQUID METAL SYSTEMS by R. C. Werner, Mine Safety Appliance Co.

11:30—VAPOR COMPRESSION EVAPORATION OF BROOKHAVEN'S RADIOACTIVE WASTES by B. Manowitz, P. Richards, Brookhaven National Lab., and R. V. Horrigan, titanium alloys mfg. div., National Lead Co.

Afternoon Session

GOLD ROOM

T. J. Walsh, Case Institute of Technology, Presiding

2:00—PRACTICAL APPLICATIONS OF STATISTICAL METHODS TO PROBLEMS IN CHEMICAL ENGINEERING by R. L. Bowles, B. F. Goodrich Co.

2:35—EVALUATION OF THE RUTHNER WASTE PICKLE LIQUOR PROCESS by N. F. Boyd and T. F. Barnhart, Blaw-Knox Co.

3:10—DRYING OF UNDEVITALIZED GLUTEN by Q. R. Jeffries, G. F. Sachsel, and R. B. Filbert, Jr., Battelle Memorial Institute.

3:45—THE NEXT PHASE OF CHEMICAL ENGINEERING, by Donald Q. Kern, The Colonial Iron Works Co.

LOUISIANA GETS NEW CARBON BLACK PLANT

A new oil-process carbon black plant is being constructed near North Bend, La., by Columbian Carbon Co., it was announced recently. Producing ultimately 60,000,000 lb. annually, the new plant will obtain raw materials from the vicinity: natural gas from near-by fields and liquid petroleum products from Gulf Coast refineries. The first unit is expected to operate in November, 1954. The completed project will cost more than $3,000,000.

ELECTROCHEMISTRY PAPERS AVAILABLE

Some of the latest results, both experimental and theoretical, in electrochemistry, presented by scientists from this country and abroad, have been collected in a volume entitled Electrochemical Constants, Proceedings of the National Bureau of Standards Semicentennial Symposium held on Sept. 19 to 21, 1951, Nat. Bur. Standards Cir. 524. The volume may be obtained for $2 from the Government Printing Office, Washington 25, D. C.

ATOMIC ENERGY REPORT AVAILABLE AT STANFORD

A second printing of Stanford Research Institute's report to the A.E.C., "Industrial Uses of Radioactive Fission Products," originally published in 1951, is available from the Public Relations Office, Stanford, Calif., for $1.50 a copy.

GERMAN REFERENCE WORK BEING PUBLISHED

The second part of the "Dechema Werkstoff Tabelle," third edition, has recently been issued as a special number of the Dechema Erfahrungsaustausch. This part records the behavior in the presence of various chemical agents of some constructional materials used in chemical engineering. On completion the volume will report on about 1,000 agents, of which 200 have so far been covered—abietic acid through benzilic acid.

The tables are published by Dechema Deutsche Gesellschaft für chemisches Apparatewesen, Frankfurt am Main, Postfach, Germany.

EARLY A.I.Ch.E. VOLUMES ARE ON MICROCARDS

Volumes 1 through 15 and the Index for the first ten volumes of the *Transactions of the American Institute of Chemical Engineers* are available in a microprint edition which may be read through a special reading machine or through any modern flat field binocular microscope. Printed on 3- by 5-in. microcards, the volumes fit into a small box or file. They may be purchased separately or at a price of $46.60 for numbers 1 through 15 from J. S. Canner & Co., Inc., 46 Millmont St., Boston, Mass.

CELANESE ANNOUNCES 20 FELLOWSHIPS

Graduate fellowships in chemical and mechanical engineering; cellulose, organic, physical, and general chemistry; physics; plastics; and textiles have been awarded to twenty students in seventeen universities and colleges by Celanese Corp. of America.

New England in the Spring

(*Continued from page 36*)

Ladies' Program

Betty Low, chairman of the Ladies' Program, has planned a gala day (Monday) at Sturbridge Village, the reconstructed old New England Village of vintage 1800. It is absolutely authentic, full of honest-to-goodness antiques. It brings back all the genuine atmosphere of Founding Fathers with its stores, forges, boot shops, and the many other early American crafts. The Committee promises to get the ladies back in time for the banquet that evening.

On Tuesday, there will be a luncheon-bridge to be held in the Hunt Room of the Sheraton Hotel. Then, there are many other places, which can be visited and enjoyed, if the ladies don't feel like playing bridge, and these are practically within a stone's throw. A visit to the first American-built Planetarium to see a review of astronomical phenomena and watch the universe travel through a million years in a few short minutes should be a "must" on everyone's list. Maybe the George Walter Vincent Smith Art Galley and the Museum of Fine Arts would hit the spot. Then there is Storrowton Village on the Eastern States Exposition Grounds where the latchstring is out at the little white entrance gate.

Golfers will find their best dreams fulfilled by the many lovely clubs and municipal courses—all just a few minutes' ride from meeting headquarters.

Finance Chairman Allen G. Erdman and general committee Chairmen Eli Perry and Francis E. Reese appear quite pleased with the entertainment planned for the Springfield meeting by William R. Ayers, program chairman.

For others, a trip to Forest Park is just what the doctor ordered. One of the foremost natural parks in the country, it covers 756 acres and is just a few minutes from the heart of the city. The beautiful mountain laurel and rhododendrons should be in bloom then, too.

A Hospitality Center will operate during the meeting to help all in need of assistance in furthering their plans. Here a visitor, anxious to make the best use of his time, will learn the how's and where's of all points of interest.

(*Continued on page 71*)

TECHNICAL PROGRAM

(Continued from page 36)

CONTROL OF RESEARCH COSTS, M. T. Carpenter, Standard Oil Company of Indiana, Chicago, Ill.

CONTROLLING COSTS IN CONSTRUCTION, Ralph E. De Simone, Construction Consultant, New York, N. Y.

CONTROL OF COSTS IN PRODUCTION, David E. Pierce, Diamond Alkali Co., Cleveland 14, Ohio; Winfield I. McNeill, Management Consultant, New York 17, N. Y.

REDUCING COSTS BY APPLICATION OF STATISTICS, Leonard A. Seder, Quality Control Consultant, Malden 48, Mass.

The Program Committee, composed of Paul A. Klingsporn, Jr., Virgil H. Hulette, Jr., Wendell K. Fitch, William R. Ayers, and Mrs. Allan W. Low, hold a meeting to decide what type of entertainment would be enjoyed most by A.I.Ch.E. members and wives attending the Springfield meeting.

TECHNICAL SESSION No. 4

Symposium on Polymeric Materials of Construction

Chairman—C. C. Winding, Cornell University, Ithaca, N. Y.

2:00 P.M.

VULCANIZABLE ELASTOMERS AS MATERIALS OF CONSTRUCTION, B. M. G. Zwicker, B. F. Goodrich Chemical Co., Cleveland 15, Ohio.

THERMOSETTING RESINS REVIEWED FOR THE CHEMICAL ENGINEER, R. J. Schatz and S. H. Rider, Monsanto Chemical Co., Springfield, Mass.

VINYL PLASTICS AS MATERIALS OF CONSTRUCTION, Raymond B. Seymour, Atlas Mineral Products Co., Mertztown, Pa.

PROPERTIES OF POLYETHYLENE, POLYTETRAFLUOROETHYLENE, POLYMONOCHLOROTRIFLUOROETHYLENE, ACRYLIC RESINS, AND CELLULOSICS, J. J. Ondrejcin, Du Pont Co., Wilmington 98, Del.

Wednesday, May 19, 1954

TECHNICAL SESSION No. 5

General Technical Session

Chairman—E. E. Lindsey, University of Massachusetts, Amherst, Mass.

(Continued on page 72)

MARGINAL NOTES

News of Books of Interest to Chemical Engineers

A Kettle of . . . Soap

Soap Manufacture, Vol. I. J. Davidsohn, E. J. Better, and A. Davidsohn. Interscience Publishers, Inc., New York (1953), 525 pp. $12.50.

Reviewed by E. A. Lawrence, Colgate-Palmolive Co., Jersey City, N. J.

This interesting volume containing much useful information on soap making by the kettle process, was written for those actively engaged in the soap industry. Those who are not directly involved and who do not know a kettle from a crutcher will find the book difficult to follow.

The first of two volumes, this one covers the theoretical aspects of soap boiling, the raw materials used, and the practical aspects of making soap in kettle and crutcher. The second volume will cover finishing operations and a description of the equipment used in boiling as well as finishing.

Since the authors gained most of their experience in Europe before World War II, they are supplying to the American reader a great deal of information from European literature and from European practice. This is a mine of experimental data particularly valuable for those who have not studied the French and German publications. The authors go on to explain the observed phenomena in terms of phase theory. They discuss the application of the soap-phase studies of J. W. McBain and others to practical soap boiling. Together with extensive discussion of kettle operations, this work will provide provocative reading—worth while for those in the field, and a "must for those concerned with kettle operations. However, a certain amount of awkward exposition and the use of special terms which are not defined make the book difficult for the uninitiated.

The reader will not find much here on the newer continuous soap-making processes. Sections on fatty raw materials and on inorganic and organic soap builders and fillers are adequate enough for those who want everything in one text. The table of contents is broken down into complete section headings which are most useful. The index is reasonably complete, but those who desire to refer to detailed data used as examples in the discussions on theory will presumably develop a special index system.

A Dish for Beginners

Introduction to Chemistry, R. T. Sanderson. John Wiley & Sons, Inc., New York (1954), 542 pp. $5.50.

Reviewed by Tod G. Dixon, Dept. of Public Works, Nassau County, N. Y.

Using a simple and direct method of expression, the author has written a readable book from the point of view of the chemist rather than that of the engineer. It contains the fundamental principles of chemistry but little discussion of the industrial applications including the method of manufacturing chemical compounds.

The text and accompanying illustrations are quite elementary, therefore this work is suitable for high-school students beginning the study of chemistry. The chapter on Periodicity is presented well and is the high spot of the book.

Separating Hydrocarbons

Hydrocarbons From Petroleum. F. D. Rossini, B. J. Mair, and A. J. Streiff. ACS Monograph No. 121, Reinhold Publishing Corp., New York (1953), 576 pp. $18.50.

Reviewed by R. H. McCormick, Assoc. Research Professor of Chemical Engineering, Pennsylvania State University, State College, Pa.

This book consists mainly of condensation of the information contained in 141 publications by American Petroleum Institute (API) Project 6 on fractionation, analysis, isolation, purification, and properties of petroleum hydrocarbons. Such a condensation was necessary to make these data available to the average research worker since it is too laborious to compile the results from individual publications.

The book should be particularly useful to those interested in (1) the preparation of pure hydrocarbons by physical separations, and (2) the analysis of petroleum fractions. The various projects for which data are given in the book are of the fundamental type; therefore, it is fortunate that the results are now available to scientists, both in industrial and in academic research work.

Of the twenty-seven chapters the first six deal with the various types of distillation procedures, and their usefulness. The next three chapters are on extraction, adsorption, and crystallization. Eight chapters describe the apparatus and techniques used to determine the various physical properties of the API standard hydrocarbon samples.

The final ten chapters include the work done by the Project on the composition of petroleum from individual fields. The most extensive work was done on a Ponca City crude oil in which the gasoline to lube oil range has been analyzed. A tabulation of all the hydrocarbons identified and isolated, along with their concentration in the crude is included. This is probably the most comprehensive study ever made on the analysis of a crude oil. Other analyses included in the book are for (1) the gasoline range from seven different petroleums, (2) a typical catalytically cracked gasoline, and (3) typical alkylates and hydrocodimers.

With all the detailed drawings of apparatus, mathematical derivations, and the physical separation charts for typical petroleum fractions, the book could be used as a standard reference or guide. There is no other book available that contains most of this information.

Books Received

Applied Electronics. Principles of Electrical Engineering Series, 2nd ed. T. S. Gray. John Wiley & Sons, Inc., New York, and The Technology Press, M.I.T., Cambridge (1954), 881 pp. $9.00.

An Introduction to Electronic Absorption Spectroscopy in Organic Chemistry, A. E. Gillam, E. S. Stern (foreword by E. R. H. Jones). Edward Arnold, London (1954), 283 pp. $8.00.

Induction and Dielectric Heating. J. Wesley Cable. Reinhold Publishing Corp., New York (1954), 576 pp. $12.50.

Organic Chemistry. 2nd ed. Reynold C. Fuson and H. R. Snyder. John Wiley & Sons, Inc., New York (1954), 544 pp. $6.50.

FUTURE MEETINGS AND SYMPOSIA OF A.I.Ch.E.

Chairman, A.I.Ch.E. Program Committee

Loren P. Scoville, Diamond Alkali Co., 300 Union Commerce Bldg., Cleveland 14, Ohio.

Assistant Chairman

George Armistead, Jr., George Armistead & Co. 1200 18th St., N.W., Washington, D. C.

MEETINGS

Springfield, Mass., Hotel Kimball, May 16-19, 1954.
TECHNICAL PROGRAM CHAIRMAN: E. Bryant Fitch.

Ann Arbor, Mich., Univ. of Mich., Ann Arbor, Mich., June 20-25, 1954—Conference on Nuclear Engineering.
TECHNICAL PROGRAM CHAIRMAN: D. L. Katz, Chairman, Dept. of Chem. and Met. Eng., Univ. of Mich., 2028 E. Eng. Bldg., Ann Arbor, Mich.

Glenwood Springs, Colo., Hotel Colorado, Sept. 12-15, 1954.
TECHNICAL PROGRAM CHAIRMAN: Dr. Charles H. Prien, Head, Chem. Div., Denver Res. Inst., Univ. of Denver, Denver 10, Colo.

Annual—New York, N. Y., Statler Hotel, Dec. 12-15, 1954.
TECHNICAL PROGRAM CHAIRMAN: G. T. Skaperdas, Assoc. Dir., Chem. Eng. Dept., M. W. Kellogg Co., 225 Broadway, N. Y. 7, N. Y.
ASST. CHAIRMAN: N. Morash, Titanium Div., National Lead Co., P. O. Box 58, South Amboy, N. J.

Louisville, Ky., Kentucky Hotel, March 20-23, 1955.
TECHNICAL PROGRAM CHAIRMAN: R. M. Reed, Tech. Dir., Gas Proc. Div., The Girdler Corp., Louisville 1, Ky.

Houston, Texas, Shamrock Hotel, May 1-4, 1955.
TECHNICAL PROGRAM CHAIRMAN: J. L. Franklin, Res. Assoc., Humble Oil & Refining Co., P. O. Box 1111, Baytown, Texas.

Lake Placid, N. Y., Lake Placid Club, Sept. 25-28, 1955.
TECHNICAL PROGRAM CHAIRMAN: L. J. Coulthurst, Chief Proc. Designer, Foster Wheeler Corp., 165 Broadway, New York 6, N. Y.

Annual—Detroit, Mich.—Statler Hotel, Nov. 27-30, 1955.
TECHNICAL PROGRAM CHAIRMAN: T. J. Carron, Supervisor, Chem. Eng. Section, Ethyl Corp., Res. Labs., 1600 West Eight Mile Road, Detroit 20, Mich.

Los Angeles, Calif., March, 1956.
TECHNICAL PROGRAM CHAIRMAN: T. Weaver, Proc. Eng., The Fluor Corp., Ltd., Box 7030, East L. A. Station, Los Angeles 22, Calif.

Annual—Boston, Mass., Hotel Statler, Dec. 9-12, 1956.
TECHNICAL PROGRAM CHAIRMAN: W. C. Rousseau, Proc. & Sales Eng., Badger Mfg. Co., 230 Bent St., Cambridge 41, Mass.

SYMPOSIA

SYMPOSIA FOR SPRINGFIELD MEETING

Polymeric Materials of Construction

Process Design

Nuclear Engineering
CHAIRMAN: D. L. Katz, Chairman (Address: See Ann Arbor Meeting).
MEETING—Ann Arbor, Mich.

Agglomeration
CHAIRMAN: A. P. Weber, International Engineering, Inc., 15 Park Row, New York, N. Y.
MEETING—Glenwood Springs, Colo.

Uranium Processing and Refining
CHAIRMAN: R. H. Long, Vitro Eng. Div., Vitro Corp., 120 Wall St., New York, N. Y.
MEETING—Glenwood Springs, Colo.

Oil Shale and Shale Oil Processing
CHAIRMAN: W. I. R. Murphy, Pet. & Oil Shale Exp. Station, U. S. Bureau of Mines, P. O. Box 621, Laramie, Wyoming.
MEETING—Glenwood Springs, Colo.

Reaction Kinetics
CHAIRMAN: N. R. Amundson, Dept. of Chem. Eng., Univ. of Minnesota, Minneapolis 14, Minn.
MEETING—New York, N. Y.

Gas Absorption
CHAIRMAN: R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.
MEETING—New York, N. Y.

Solvent Extraction
CHAIRMAN. Dr. R. B. Beckmann, Dept. Chem. Eng., Carnegie Inst. of Tech., Schenley Park, Pittsburgh 13, Pa.
MEETING—New York, N. Y.

New Processes Utilizing Moving Beds
CHAIRMAN: N. Morash, Tit. Div., National Lead Co., P. O. Box 58, South Amboy, N. J.
MEETING—New York, New York

Heat Transfer
CHAIRMAN: R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.
MEETING—Louisville, Ky.

Nucleation Processes
CHAIRMAN: D. W. Oakley, Plant Mgr., Metal & Thermit Corp., 1 Union St., Carteret, N. J.
MEETING—Houston, Tex.

Unscheduled

Centrifugation
CHAIRMAN: J. O. Maloney, Chairman, Dept. Chem. Eng., Univ. of Kansas, Lawrence, Kan.

Extraction of Hydrocarbons for Chemical Use from Pipe Line Gases
CHAIRMAN: E. E. Frye, J. F. Pritchard & Co., 210 W. 10th, Kansas City 5, Mo.

Submitting Papers

Members and nonmembers of the A.I.Ch.E. who wish to present papers at scheduled meetings of the Institute should follow the following procedure.

First, write to the Secretary of the A.I.Ch.E., Mr. S. L. Tyler, American Institute of Chemical Engineers, 120 East 41st Street, New York, requesting three copies of the form "Proposal to Present a Paper Before the American Institute of Chemical Engineers." Complete these forms and send one copy to the Technical Program Chairman of the meeting for which the paper is intended. one copy to the Assistant Chairman of the A.I.Ch.E., Program Committee, address at the top of this page, and one copy to the Editor of Chemical Engineering Progress, Mr. F. J. Van Antwerpen, 120 East 41st Street, New York.

If you wish to present the paper at a particular symposium, one copy of the form should go to the Chairman of the symposium instead of the Technical Program Chairman of the meeting.

Before Writing the Paper

Before beginning to write your paper you should obtain from the meeting Chairman, or from the office of the Secretary of the A.I.Ch.E., at 120 East 41st St., New York, a copy of the A.I.Ch.E. Guide to Authors, and Guide to Speakers. These cover the essentials required for submission of papers to the A.I. Ch.E. or its magazines.

Copies of Manuscript

Five copies of each manuscript must be prepared. For meetings, one should be sent to the Chairman of the symposium, and one to the Technical Program Chairman of the meeting at which the symposium is scheduled. If no symposium is involved, the two copies should be sent to the Technical Program Chairman. The other copies should be sent to the Editor's office since manuscripts are automatically considered for publication in Chemical Engineering Progress, or the symposium series of Chemical Engineering Progress, but presentation at a meeting is no guarantee that they will be accepted.

DEADLINE DATES FOR PAPERS

GLENWOOD SPRINGS MEETING—May 12, 1954

NEW YORK MEETING—August 12, 1954

LOUISVILLE MEETING—November 20, 1954

HOUSTON MEETING—January 1, 1955

LAKE PLACID MEETING—May 25, 1955

DETROIT MEETING—July 27, 1955

LOS ANGELES MEETING—No definite date as yet

BOSTON MEETING—August 9, 1956

New England in the Spring

(*Continued from page 66*)

So, chemical engineers, make your plans and join us for our Spring National Meeting, May 16-19, 1954, here in the heart of New England. This will be a meeting where you can mix business with pleasure and enjoy New England at its best.

Plant Trips

The plant trips committee—chairmaned by Ralph W. Hastings, Shawinigan Resins Corp., have lined up the following fine trips:

1. United Aircraft Corp.'s Hamilton-Standard Division

The primary activity of Hamilton-Standard is the production of propellers for every type of propeller-driven aircraft, both military and civilian. Air-conditioning systems, fuel controls, starters, hydraulic-system power pumps, and other equipment for the aircraft industry are also produced.

The plant was constructed in 1951 on a 280-acre site representing the best in plant location and layout features.

Certain sections are strictly classified and will not be open to visitors. Those members wishing to take this trip must *register at least three weeks in advance and be prepared to prove citizenship.*

2. Prophylactic Brush Co.

The Prophylactic Brush Co. and its predecessors have a complete line of plastics-molding operations—both injection and compression types—using a wide variety of plastics materials.

All phases of modern plastic molding and brush manufacture will be seen in this up-to-date plant.

3. Bigelow-Sanford Carpet Co.

This trip is one which may be attractive to both the ladies and the men.

Bigelow-Sanford's 3,000 employees operate modern power machinery to produce the three popular types of carpet (Wilton, velvet or tapestry type, and Axminster.)

Guests who take this trip will see the many operations in the production of these types of carpet—from raw wool to the finished product.

In addition, there is a complete small-scale pilot plant for carpet research and development which may be visited.

4. A. G. Spalding & Bros., Inc.

Spaldings' large modern plant engaged in the manufacture of equipment for baseball, football, tennis, golf, and basketball will be exhibited, and the proc-

New England in the Spring

(*Continued from page 71*)

essing of wood, leather, rubber, and metal, involved in such manufacture, will also be viewed.

5. Monsanto Chemical Co. and Shawinigan Resins Corp.

The plastics division of Monsanto Chemical Co. produces a wide variety of plastics materials. Phenolic resins of many types, styrene plastics, vinyl chloride plastics and vinyl butyral safety glass plastic are among the products of this plant.

Shawinigan Resins Corp., a subsidiary of Monsanto, is located adjacent to the plastics division. It produces vinyl acetate resins of various types, including vinyl butyral resins for use in safety glass.

Some of the typical manufacturing operations in these plants will be seen during the plant trip to this location.

6. United States Rubber Co.

Largest tire plant east of the Alleghenies, the Fisk Tire plant of the United States Rubber Co. manufactures auto, truck and bicycle tires and tubes and retreading rubber. Visitors can see rubber as it arrives from Malayan plantations, and watch it being mixed with chemicals and combined with textiles and steel. All parts of the processing from raw rubber to the finished tire ready for the new cars or for the tire dealer will be demonstrated.

TECHNICAL PROGRAM

(*Continued from page 67*)

9:00 A.M.

COCURRENT GAS ABSORPTION, W. S. Dodds and L. F. Stutzman, Northwestern University, Evanston, Ill.

LIQUID FILM EFFICIENCIES ON SIEVE TRAYS, Alan S. Foss and J. A. Gerster, University of Delaware, Newark, Del.

COMPENSATION FOR HYDRAULIC GRADIENT BY BUBBLE CAP STAGING IN A LARGE FRACTIONATING TOWER, J. A. May, The Dow Chemical Co., Freeport, Tex., and Joseph C. Frank, The Dow Chemical Co., Midland, Mich.

PERFORMANCE OF PACKED COLUMNS I, TOTAL, STATIC, AND OPERATING HOLDUPS, H. L. Shulman, C. F. Ullrich, and N. Wells, Clarkson College of Technology, Potsdam, N. Y.

PERFORMANCE OF PACKED COLUMNS II, WETTED AREAS, EFFECTIVE INTERFACIAL AREAS, GAS PHASE MASS TRANSFER RATES AND LIQUID PHASE MASS TRANSFER RATES, H. L. Shulman, C. F. Ullrich, A. Z. Proulx and J. O. Zimmerman, Clarkson College of Technology, Potsdam, N. Y.

(The End)

CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions.

These names are listed in accordance with Article III, Section 7, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Active members will receive careful consideration if received before May 15, 1954, at the Office of the Secretary, A.I.Ch.E., 120 East 41st Street, New York 17, N. Y.

Applicants for Active Membership

Aaron, John B., *Swarthmore, Pa.*
Alexander, Cruzan, *New York, N. Y.*
Burch, James M., *University City, Mo.*
Butler, Benjamin B., *Seattle, Wash.*
Clancey, C. D., *Harrisonburg, Va.*
Clark, H. N. *Carlsbad, N. M.*.
Delahanty, William J., *Carneys Point, N. J.*
Durland, Lawrence V., *Salt Lake City, Utah*
Ergun, Sabri, *Pittsburgh, Pa.*
Faulkinberry, Frank A., *Sheffield, Ala.*
Gasser, Max G., *New Brunswick, N. J.*
Gerhart, Ray V. D., *Awali Bahrain, Persian Gulf*
Girdler, Robert M., *Aiken, S. C.*
Gradishar, Frederick J., *Woodbury, N. J.*
Gregory, John M., *Ashtabula, Ohio*
Grice, Harvey H., *Kankakee, Ill.*
Guthrie, Hugh D., *Wood River, Ill.*
Hamilton, John C., *Shawinigan Falls, Quebec, Canada*
Hammesfahr, Frederic W., *Pittsfield, Mass.*
Harned, W. L. *Kingsport, Tenn.*
Kaplan, Herbert, *Irvington, N. J.*
Kelley, William N., *New Haven, Mo.*
Kuechler, William L., *Grand Island, N. Y.*
Lawler, Arthur, *Colonia, N. J.*

(*Continued on page* 000)

CANDIDATES

Maret, M. W., *St. Albans, W. Va.*
McBride, E. O., *Baytown, Tex.*
McKlveen, John R., *Clarkwood, Tex.*
Meiser, Kenneth D., *Toledo, Ohio*
Moore, Paul R., *N. Augusta, S. C.*
Muddiman, John B. C., *Augusta, Ga.*
Neben, Ernest W., *Rochester, N. Y.*
Olson, Austin C., *Berkeley, Calif.*
Olson, Robert C., *Oak Ridge, Tenn.*
Peters, Frank M., *Wyandotte, Mich.*
Potts, John M., *Florence, Ala.*
Puxley, Philip A., *Arvida, Quebec, Canada*
Rose, E. A., *Baytown, Tex.*
Rule, Kenneth C., *Noroton Heights, Conn.*
Shafer, S. I., *Edgewater, N. J.*
Sims, Mearlin L., *Nitro, W. Va.*
Smith, Ben W., Jr., *Lake Jackson, Tex.*
Sowers, Byron L., *Lockport, Ill.*
Spangler, Samuel F., *Scarsdale, N. Y.*
Spiess, Newton E., Jr., *Oakdale, L. I., N. Y.*
Strunk, Edward, *Old Ocean, Tex.*
Teykl, Irvin F., *Houston, Tex.*
Thomson, Robert, *Charleston, W. Va.*
Treichler, R. K., *Freeport, Tex.*
Von Berg, Robert, *Midland, Mich.*
Wallace, James L., *Springfield, Mass.*
Wihera, E. J., *Claymont, Del.*
Wiitala, Edwin S., *Rochester, N. Y.*

Applicants for Associate Membership

Allen, Donald R., *Gainesville, Fla.*
Claunch, Terrell C., *Port Arthur, Tex.*
Hall, Raymond C., *Manhattan, Kan.*
Johnson, William C., *Kalamazoo, Mich.*

Applicants for Junior Membership

Adler, Irwin L., *Jersey City, N. J.*
Alsys, C. M., *Drexel Hill, Pa.*
Anderson, David M., *Jamaica Plain, Mass.*
Anderson, John E., *Hammond, Ind.*
Barrett, Paul A., *Danville, Pa.*
Barson, Norman, *Ames, Iowa*
Bearinger, Joseph W., *Wright-Patterson, Ohio*
Bednar, Thomas N., *Akron, Ohio*
Bird, R. Byron, *Madison, Wis.*
Bishop, John V., *Midland Mich.*
Blackburn, W. Robert, *Destrehan, La.*
Blair, John A., *Aiken, S. C.*
Brannick, Boris, *Orange, Tex.*
Bryant, Howard S., Jr., *Oak Ridge, Tenn.*
Collins, James P., *New Haven, Conn.*
Coombs, Garth, *Paramus, N. J.*
Coon, Richard P., *N. Augusta, S. C.*
Crouch, J. E., *Anniston, Ala.*
Daniels, David A., *Springfield, Mass.*
Darr, D. E., *Doylestown, Ohio*
Elgal, G. M., *Edwards, Calif.*
Fishlock, Robert E., *Buffalo, N. Y.*
Fogg, Edward T., *Woodstown, N. J.*
Forgrieve, John, *Plainfield, N. J.*
Gallagher, James J., *Augusta, Ga.*
Gans, Daniel, Jr., *Milton, Mass.*
Gardella, Richard George, *Niagara Falls, N. Y.*
Gaynor, Joseph, *Cleveland, Ohio*

CANDIDATES

Gealer, Roy L., *Detroit, Mich.*
Gillam, William L., *Philadelphia, Pa.*
Goodson, J. Lee, Jr., *Texas City, Tex.*
Harrod, Douglas Clarence, *Reading, Ohio*
Heaston, Robert J., *Wright-Patterson, Ohio*
Henze, Edward D., *Army Chemical Center, Md.*
Hill, Charles E., Jr., *Houston, Tex.*
Hooper, Robert W., *Havertown, Pa.*
Huston, R. F., *Lake Jackson, Tex.*
Hutton, R. N., III, *So. Charleston, W .Va.*
Isler, R. J., *Upton, L. I., N. Y.*
Jaskulski, Matthew W., *New Castle, Del.*
Jensen, Harry F., *Oak Park, Mich.*
Johnston, George E., *Wood River, Ill.*
Kalvin, George A., Jr., *Terre Haute, Ind.*
King, Herbert H., *Brewster, N. Y.*
Klemenic, John., *Cameo, Colo.*
Lark, Raymond F., *Baton Rouge, La.*
Larson, O. Owen, *Harvey, Ill.*
Leavitt, William C., *Pittsfield, Mass.*
Leslie, Albert J., *Wilmington, Del.*
Litty, Albin, *Broomall, Pa.*
McBeth, Lloyd Theodore, *College Station, Tex.*
McCarthy, P. Gregory, *Augusta, Ga.*
Meadows, E. Lee., *Charleston, W. Va.*
Meglis, Theodore George, *Avenel, N. J.*
Multur, Robert K., *Chesterton, Ind.*
Munson, Thurmond A., Jr., *Angleton, Tex.*
Nelson, Richard J., *New York, N. Y.*
Papailias, John G., *New York, N. Y.*
Parrone, John J., *Lynchburg, Va.*
Pearl, Wesley L., *Richland, Wash.*
Peters, J. Irwin, *Wilmington, Del.*
Rockwell, Frank E., Jr., *Blue Ridge, Ga.*
Roskey, Michael L., *Minneapolis, Minn.*
Roth, Leo, *Denver Colo.*
Rumps, Paul P., Jr., *Detroit, Mich.*
Schwarz, Robert J., *Chicago, Ill.*
Singley, Wilbur J., Jr., *Pittsburgh, Pa.*
Slaughter, Wilbur Hayes, *Philadelphia, Pa.*
Smith, Albert Rossi, *Cincinnati, Ohio*
Smith, Buford D., *Baytown, Tex.*
Steiger, Leonard W., Jr., *Danville, Pa.*
Stepniewski, Daniel D., *Schenectady, N. Y.*
Stewart, Warren E., *Park Forest, Ill.*
Sullivan, Wayne L., *Wyandotte, Mich.*
Tepper, Edward H., *Portsmouth, Ohio*
Thiede, Roger A., *Richland, Wash.*
Titus, Rayburn L., *Alton, Ill.*
Weaver, David E., *Cuyahoga Falls, Ohio*
Wicks, Charles E., *Albany, Ore.*
Wilde, B. W., *LaMarque, Tex.*
Wong, Morton Min, *Boulder City, Nev.*
Zonis, Meyer L., *Stamford, Conn.*

E. J. C. REPORTS ON SUPPLY AND DEMAND

A report entitled "Distribution of Engineering Graduates and Demand for Engineers, 1953," has been issued by the Engineers Joint Council, 29 West 39 Street, New York City 18. Based on two surveys by the Special Surveys Committee of E.J.C., the report summarizes the findings and presents them in tabular form.

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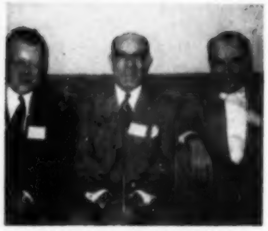
NATIONAL MEETING

(Continued from page 41)

Pres. C. G. Kirkbride and Defense Asst. Secy. Quarles.

A. C. Fieldner, M. T. Bennett & G. G. Brown.



L. C. Byck, Jr., G. K. Walton & W. Sackett.

with mixing theory—the further development of mass-transfer analysis for the determination of "agitation number," useful in design.

PREDICTION OF PROPERTIES OF COMPOUNDS FROM THEIR STRUCTURE might possibly eliminate the need for some laboratory and pilot plant work. . . . F. A. Landee and V. E. Whittier revealed the methods being employed by Dow Chemical. Word is going around that Landee entertains his chemical friends at home with the game "You name the compound and I'll tell you its properties" . . . and more times than not, he turns out a handbook—correct answer!

MIXER SETTLER extraction units have undergone extensive development for the isotopes separations for A. E. C. . . . Now Fenske (Penn State U.) and Long (Standard Oil Development) have described an experimental unit, designed for rapid experimental solution of complex extraction problems—can be varied to provide an effect ranging from 1 to 20 stages. . . .

FOR A BETTER UNDERSTANDING OF FUNCTIONS: Absorption of nitrogen oxides in water (an important step in nitric acid production, and in the cleaning of stack gases) by Peters, Ross & Klein (U. of Illinois) . . . . Atomization of molten wax and molten metal in air at the throat of a venturi nozzle, by Wetzel & Marshall (U. of

M. Souders, Jr. ▶

C. G. Kirkbride, U. S. Sen. Symington & G. Armistead, Jr. ▼

M. Sittig & W. C. Schroeder.

Wisconsin) . . . inside resistance to mass transfer for drops of water falling through carbon dioxide by Hughes & Gilliland (MIT). . . .

DESIGNERS' AIDS: Vapor - liquid equilibria, essential for design of equipment for distillation or absorption, now determined more precisely by a method of total pressures, by Holtzlander & Riggle (Du Pont, eng. dept., Wilmington). . . . Severns, Perry Pigford (U. of Delaware) presented a method for estimation of vapor-liquid equilibria for ternary systems from binary data, difficult in the past. . . . Johnson, Huang & Talbot (U. of Toronto), mathematical analytical methods for batch fractionation . . . Edmister & Ruby (Calif. Res. Corp.) devised and employed a system of computations for vapor-liquid equilibria of hydrocarbons as functions of reduced temperature, reduced pressure, and boiling-point ratio, which permits extension beyond the range of the original work by Benedict, et al. . . . Parisi & Joffe (Newark College of Engineering), a correlation from which the number of theoretical plates for a given separation by distillation can be estimated as a function of the reflux ratio. . . .

GOOD NEWS: About the Army Scientific & Professional Personnel Program which was reported as materially assisting the effective utilization of scientists and engineers on active military duty (Leibson & Cacoso, Chem. Corps, Frederick, Md.).

(The End)

LOCAL SECTION

Describing the operation of the Small Samples Preparation Laboratory of the Hercules Powder Co. and the versatility of its many unit operations in regular use, Robert Meyers, associated with that company's Experimental Station in Wilmington, Del., addressed the first meeting of 1954 of the Tidewater Virginia Section. The meeting was held Feb. 10 in Colonial Heights.

J. H. Hill, chairman, Public Relations Committee, reported on the activities of the section, including in his account the names of the officers of the section. These officers are:

Chairman—M. E. Kalen, textile fibers dept., Du Pont Co.
Vice-Chairman—Danial Post, nitrogen div., Allied Chem. & Dye
Secretary—R. W. Nash, film dept., Du Pont Co.
Treasurer—G. Kiopekly, nitrogen div., Allied Chem. & Dye
Directors—D. R. Walton, textile fibers dept., Du Pont Co.
R. H. Keane, Virginia-Carolina Chem. Co., W. L. Stafford, Hercules Powder Co.
R. L. Tilton, nitrogen div., Allied Chem. & Dye.

Warren Gray of the Taylor Instrument Co. showed a film "Instrumentation at Work."

How the American people are relieved of three billion dollars of their money each year without their vociferous objection was told in a talk "The Run for Your Money" given before the Rocky Mountain Section by Dan Bell, general manager of the Denver Better Business Bureau. He declared the schemes of the gyp artist are many and varied.

R. M. Berry sent in the names of the newly elected officers for 1954. They are

Chairman—Paul Manning, Stearns-Roger Mfg. Co.
Vice-President—Leo Roth, Gates Rubber Co.
Secretary-Treasurer—George Galloway, Julius Hyman and Co.

M. L. Gernert reports that the East Tennessee Section staged a plant tour of the Borden Mills, Inc., on March 20. Emphasis was placed on the material-handling equipment.

Tracing the growth of acoustical engineering from a branch of physics to an engineering field in itself over the past twelve years, Conrad Hemond, project manager and consultant with the Industrial Sound Control Company of Hartford, addressed the March 2 meeting of the Western Massachusetts Section. He said that psychological and physiological aspects of the field are assuming large importance, particularly in industry. This field, he added, is divided into three major branches, i.e., architectural or psycho-acoustics, general consulting, and applications (construction, materials, and built-in noise reduc-

tion at the source). Mr. Hemond has had considerable experience both in the teaching and industrial fields.

C. H. Fawkner sent in a detailed story of this meeting and included the names of the 1954 officers of the section. They are

Chairman..............E. E. Lindsay
Chairman-Elect.........V. H. Hulette
Treasurer...............R. T. Bogan
Secretary..................D. Rogers
Directors—F. W. Hammesfahr and A. W. Low

This section is busy with plans for the May meeting. (*See* page 35.)

Additional information on the Fifth Annual Chemical Engineering Symposium to be presented by New Jersey Section in Newark, N. J., has been sent in by Roger Walwark, III. At the morning session on May 11 "Practical Aspects of High Solids-Low Liquid Mixing" will be given by J. L. Diltz, J. H. Day Co., Cincinnati, Ohio, and at the afternoon session "Building the Will to Work" by W. V. Machaver, assistant director of personnel, Johnson and Johnson, Inc., New Brunswick, N. J.

Lincoln T. Work, consulting engineer, one of the speakers at the one-day meeting.

Reporter Walwark wants us to tell you that the registration fee, which includes reprints of the technical papers, will be $3.00 for New Jersey Section members, $1.00 for students, and $4.00 for all others.

"Natural Gas Oxidation" was the subject of a talk given by O. V. Luke, chief physical chemist for the research and development department of the Celanese Corporation of America, before the March 19 meeting of the South Texas Section. An inspection trip and complete tour of the Platformer-Udex of the Great Southern Chemical Co., Corpus Christi, Tex., featured the meeting.

The month previous the section made an inspection trip to the effluent treating and disposal facilities of the Humble Oil & Refining Co., Baytown, Tex. At that meeting N. S. Chamberlin, chemical engineer, technical service division, Wallace & Tiernan Co., Inc., gave a talk titled "The Role of Chlorine in Treating Industrial Water and Waste Water."

A panel discussion on "Chemical Engineering As a Professional Career" featured the March 24 meeting of the Rochester Section. Those who took part in it were: A. K. Ackoff, senior engineer, engineering division, Kodak Park; F. W. Kunkel, supervisor of engineering and maintenance, chemical manufacturing division, Kodak Park; James Y. Oldshue, head of research and development department, Mixing Equipment Co.; J. H. Rushton, Director, A.I.Ch.E. and professor and director, chemical engineering department, Illinois Institute of Technology, and Irving Siller, chief, heat-exchanger section, Pfaudler Co. After the panel discussion a new technical film in sound and color titled "Fluid Mixing" was shown by representatives of Mixing Equipment Co., Inc.

A dinner at the Faculty Club of the University of Rochester preceded the meeting. The panel discussion was held in the Chemistry Building. This was the annual meeting with the University of Rochester Student Chapter.

At the Feb. 27 meeting, the annual meeting of the Rochester Engineering Society in cooperation with local engineering societies, "Modern Aerial Photographic Reconnaissance" was the title of a speech delivered by Brigadier General G. W. Goddard of the Bulova Research and Development Corp. The lecture was illustrated with a series of slides showing aerial camera equipment as used in military jet aircraft, and photographic results. General Goddard is a graduate of the U. S. School of Military Aeronautics and Cornell University. He is the recipient of various U. S. and foreign medals and awards. William H. Eilinger reported these meetings.

The new, improved, and less costly products made possible by technical advances in the fiberglass industry were described by C. A. Smucker, technical personnel manager of the Owens-Corning Fiberglas Corp., at the February meeting of the Central Ohio Section held at the Faculty Club of Ohio State University.

Results of the election of officers for 1954 were announced as follows:

Chairman—K. S. Jacobs, The Ironsides Co.
Vice-Chairman—R. B. Filbert, Jr., Battelle Memorial Inst.
Secretary-Treasurer—E. E. Smith, Ohio State University
Executive Committee—C. J. Geankoplis (past chairman), Ohio State University; J. W. Salter, Keever Starch Co.; and E. E. Slowter, Battelle Memorial Inst.

E. E. Smith and G. F. Sachsel sent in accounts of the meeting.

H. B. Addoms, reporter for the Western New York Section, informs us that the March 10 meeting was a new type of informal meeting, which included round-table discussions held simultaneously. Discussion leaders and their topics were:

W. C. Brooks—Welding
T. E. Corrigan—What Good is Thermodynamics?
J. W. Faasen—Quick Investment Estimates
R. B. MacMullin—Solving Problems with Insufficient Data
A. H. Maude—Is the Process Ready for Pilot Plant?
A. I. Mendolia—Plant Start-Ups

Some aspects of civil law, as applied to the private and professional life of the engineer, were discussed before the Columbia Valley Section on Feb. 16 by J. T. Day, who is resident attorney at the 110 million dollar Hanford construction project of Kaiser Engineers, division of Henry J. Kaiser Corp.

A few weeks previous the section was the guest of the Columbia Section, A.S.C.E., at a showing of colored movies on the design, construction, and operation of oil pipe lines. H. H. Anderson, vice-president and general manager of Trans-Mountain Oil Pipe Line Co., showed two movies; one described a pipe line constructed in the Midwest, and the other depicted the line recently completed between Edmonton, Alta., and Vancouver, B. C. B. Lyle Lex sent in news of these and other meetings of his section.

ONE-DAY MEETINGS

Cleveland, Ohio—April 23, Hotel Carter

Philadelphia-Wilmington—April 27, University of Pennsylvania Museum, Philadelphia

New Jersey—May 11, Essex House, Newark

At the March 3 meeting of the Detroit Section, T. E. Wannamaker of Orangeburg, S. C., gave a talk titled "How to Start a Small Chemical Business." According to D. W. Anderson, reporter, this section's members are beginning to talk about the annual plant trip. More about the trip later.

In a speech titled "Some Notable Commercial Applications of the Fluid Bed Technique," L. V. Lee, sales engineer for the Dorr Co., Stamford, Conn., said that this field originated with the oil industry where petroleum gases are "cracked" during contact with suspended particles of solid catalysts which remain unreacted and are used over. He told of the Dorr Co.'s developments of the same concept in the reverse direction—reaction of solid particles with hot gases whose updraft suspends them in layers of man-made, dry quicksand called "fluid beds." The floating fluidized particles heat up and react faster than do solid particles sliding through older style revolving kilns. He asserted further that the Dorr FluoSolids reactors use about 25% less heat than kilns do. These remarks of Mr. Lee were made at the March 16 meeting of the St. Louis Section. Richard Kerlin sent in a story on this meeting and included the names of the officers recently elected. They are

Chairman—D. F. Chamberlain, Washington University

Vice-Chairman—C. B. Roen, Monsanto Chemical Co.

Secretary—A. T. Pickens, C. K. Williams & Co.

Treasurer—Ralph Cook, Olin Industries

The March 11 meeting of the Akron Section was a triple-barrel affair featuring three well-received talks. Dr. Jean LeBras, French rubber chemist and director of the French & Indo-Chinese Rubber Research Institutes, showed and described a number of slides on various rubber plantations and plant installations in Indo-China. Herman Thies, general manager, chemical division, Goodyear Tire & Rubber Co., gave a talk in conjunction with a moving picture taken on a trip he made down the San Juan Canyon in Utah. O. J. Britton, chemical engineer, research department, Pfaudler Co., Rochester, N. Y., described the process of the fabrication of steel vessels and the application of glass to these vessels. He outlined the uses of these in the chemical industry. A discussion of thermal shock and field-repair techniques was also covered.

At the Feb. 11 plant tour of the Ohio Boxboard Co., Rittman, Ohio, approximately 150 members and guests saw four paper-board machines in operation, producing about 600 tons of paper board a day. Supplementing the four basic machines were two high-speed corrugators for the production of corrugated container board. H. L. Nicholson, reporting on this tour arranged by W. J. Smithwick, chemical engineer on the technical staff of Ohio Boxboard and who is also a member of the Akron Section, said that other facilities viewed covered all types of printing presses, including a high-speed Rotogravure press, various types of blanking machines and high-speed folding carton gluers.

An inspection trip at the William Powell Co. plant No. 2 in Cincinnati, Ohio, was made by members of the Ohio Valley Section on March 1. In this plant larger valves in iron, steel, and alloys for all pressures and services are manufactured. Section members observed the techniques for testing valve casting by means of gamma rays and Magnaflux. N. W. Morley writes that a complete display of finished products, including sectional cutaways of special motor-operated valves, was especially interesting to the group.

After a dinner in the Oak Room at Fenn College on Feb. 23, eighty members and guests of the Cleveland Section heard a talk by C. N. Bradley, Jr., of the textile fibers department of Du Pont Co., speak on "Your Life and Man-Made Fibers." D. J. Porter, reporter, states that the talk inspired a "long cross-examination by the ladies present."

"Something Has Been Added," a talk primarily concerned with the use of additives for petroleum products, was given by Leslie C. Beard, Jr., president of the American Society for Testing Materials and assistant director of Socony-Vacuum Laboratories, at the Feb. 23 meeting of the Southern California Section held at C. F. Braun &

Co. This meeting was a joint affair with the Southern California Section of the American Society for Testing Materials. Approximately ninety members and guests of the A.I.Ch.E. section attended, along with 140 members and guests of A.S.T.M.

At the January meeting Wilbur Long, Fluor Corp., discussed the use of models as an aid to plant design. He cited examples where models have saved money in planning, drafting, and constructing plants.

On April 20 this section will hear J. E. Toevs, Shell Chemical Corp., and R. C. Miller, Stanford Research Institute, explain "Growth Trends in the Chemical Industry." An open forum for floor discussion will immediately follow the speeches. Messrs. Kuist and Class sent reports of these meetings.

"What Management Expects From a Young Chemical Engineer" was the topic of a panel discussion at a recent meeting of the Charleston Section with 300 members and guests present. Members of the panel were C. W. Atwood, general superintendent, Carbide and Carbon, Institute, W. Va., J. Cresce, manager, Monsanto, Nitro, W. Va., W. S. Brackett, vice-president, Carbide and Carbon, F. A. Otto, plant manager, Du Pont, Belle, W. Va., S. W. Pickering, II (moderator), director, industrial relations, Carbide and Carbon, South Charleston, W. Va., W. Q. Smith, manager, technical section, Du Pont, Belle, K. H. Rowland, general superintendent, Carbide and Carbon, South Charleston, W. Va. and J. H. Mooney, plant manager, Westvaco, South Charleston. In his communication to us, A. C. Hyde listed the pertinent and significant remarks of each speaker.

"Chemical engineers must become better mathematicians if we are to find the answer to process cost variables." In these words D. Q. Kern, director of engineering, chemical and process equipment division, Colonial Iron Works, Cleveland, Ohio, addressed the Northeastern New York Section. He advocated that companies use engineers qualified in higher mathematics to find rational methods for process design. This section joined student affiliates from Rensselaer Polytechnic Institute to hear Dr. Kern. Reporter Schafer remarked that the advance notice on Dr. Kern as a humorous and interesting speaker was not exaggerated.

Sabine Area members currently holding office are:

Chairman .... **F. M. Tiller**
Chairman-Elect .... **W. V. Osgood**
Secretary-Treasurer .... **B. C. Ball**
Directors: Z. D. Bonner, Ben King, A. W. Olschefski

Ben C. Ball, Jr., sent in these names along with a résumé of the activities of the Sabine Area Section for 1953.

H.R.G.

A. I. Ch. E. MEMBERSHIP INFORMATION

S. L. TYLER, *Secretary*
American Institute of Chemical Engineers
120 E. 41st St., New York 17, New York

Dear Sir: Please send me information regarding membership requirements. 4-54

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PEOPLE

Loren P. Scoville, since 1951 vice-president in charge of engineering, purchasing, and operations for Jefferson Chemical Co., New York, and an active member of A.I.Ch.E., has been named director of engineering for the Diamond Alkali Co., Cleveland, Ohio. As stated by R. F. Evans, president of the company, the addition of Mr. Scoville "brings a recognized chemical processing authority into the company . . ."

Mr. Scoville has had long experience in process engineering. At the Texas Co. he was responsible for the chemical engineering design and economic studies of several large refinery process installations. When the Jefferson Chemical was formed in 1944 he was made chief engineer and shortly thereafter was put in charge of plant design and construction. Subsequently his responsibilities included plant operations.

After earning his B.S. degree from the University of Redlands, Redlands, Calif., and his master's in chemical engineering from California Institute of Technology, Pasadena, he began his career with Southwestern Engineering Co., Los Angeles, in 1930.

In both local and national affairs of A.I.Ch.E., Mr. Scoville has been active. Locally he held offices in the New York Section including the chairmanship, and nationally served on the Committee on Admissions. He is now chairman of the Program Committee, Publications Committee, and the Publications Board.

Max O. Debacher, formerly assistant sales manager for Saflex, a product of Monsanto Chemical Co., is now assistant manager of overseas plastics manufacture, plastics division. Mr. Debacher joined the Fiberloid Corp. in 1937, the year before that company was acquired by Monsanto. He was associated with the research department, serving since 1947 as group leader on Saflex polyvinyl butyral, the plastic interlayer used in the manufacture of safety glass. In 1949 Debacher joined the sales department as technical service representative for Saflex.

Bruce H. Sage, professor of chemical engineering, California Institute of Technology, Pasadena, Calif., was recently awarded the Anthony F. Lucas Gold Medal for 1954 by the American Institute of Mining and Metallurgical Engineers "for his distinguished achievements in research." During the war he supervised the Propellant and Interior Ballistics Section of the Caltech rocket project and his investigations and contributions earned him the U. S. Medal for Merit in 1948.

Proctor H. Avon has been appointed director of engineering, organic chemicals division, Monsanto Chemical Co., effective April 1. Chief engineer since September, 1953, of the titanium research project conducted by Monsanto and National Research Corp. Avon previously had been division engineer of Monsanto's Merrimac Division.

Harry B. McClure, executive vice-president of Carbide and Carbon Chemicals Co., a division of Union Carbide and Carbon Corp. since August, 1953, has been appointed president. He has been a member of the organization since 1928 when he joined Union Carbide as a Research Fellow on the Carbide and Carbon Chemicals Fellowship at the Mellon Institute of Industrial Research, in Pittsburgh. Through the years he has been technical representative in the Philadelphia area, in sales development work in New York, and for the past twenty years has been concerned with the development of new chemicals and their use.

William P. Hegarty, a recent graduate of the University of Michigan with a bachelor's degree in chemical engineering, has joined the staff of Standard Oil Development Co. at the Esso engineering department in Linden, N. J.

Lee H. Clark has recently been appointed president of Sharples Chemicals Inc., Philadelphia, Pa. With the company for twenty-five years, he has been executive vice-president since 1950 and in charge of manufacturing operations since 1929.

Maurice F. Dufour, a member of Freeport Sulphur Co. since 1933, has been appointed assistant vice-president of that company. He has been manager of development since 1951. At present he is in charge of the company's project to develop nickel and cobalt at Moa Bay in Cuba. During 1943 and up to 1947 he was assistant general manager and then general manager of the nickel mining plant which Freeport designed, built, and operated for the U. S. Government at Nicaro, Cuba.

The appointment of **V. E. Wellman** as manager of the petrochemicals and the intermediate and rubber-chemicals departments, American Cyanamid, has been announced. Prior to this appointment, Dr. Wellman was assistant manager of that department. He joined the former Calco chemical division, American Cyanamid Co. in 1945 as associate director of process development and in 1951 became director of process engineering. He was formerly director of purchases, chemical division, B. F. Goodrich Co., and assistant sales manager, solvents department, R. W. Greeff Co., New York.

Samuel N. Johnson is the new project engineer, chemical materials department at the General Electric phenolic products plant, Pittsfield, Mass. He joined G.E. in 1939 at the Pittsfield transformer division and subsequently was transferred to the chemical division laboratory, where he remained until his present appointment.

Witco Chemical Co. has announced the appointment of **Cyrus E. Silling, Jr.,** as manager of the plastics chemicals division with headquarters at the company's main office in New York. Mr. Silling was with the Ohio Apex division of Food Machinery & Chemical Corp. before he joined Witco, and prior to that he had been associated with Hercules Powder Co. He received his B.S. degree from Carnegie Institute of Technology in 1944.

Robert W. Moulton has been appointed sales manager at Applied Physics Corp., Pasadena, Calif. Mr. Moulton was formerly with Beckman Instruments, Inc., where he was assistant general sales manager.

The promotion of **Wallace F. Armstrong** from manager of the Houston plant to assistant general manager of manufacturing has been announced by Ethyl Corp. He joined Ethyl in 1939 as an operating supervisor, was named superintendent of ethyl chloride operations at the Baton Rouge plant in 1945, and promoted to manager of the Houston plant two years ago.

William H. Congleton was elected a director of Baird Associates, Inc., Cambridge, Mass., at the recent annual meeting of stockholders and directors. Mr. Congleton is the technical director of American Research & Development Corp., and a director of Magnecord, Inc. He was associated with American Research & Development and at one time was group leader in petrochemical economic research for Standard Oil Co. (Ind.).

Oscar J. Swenson was recently appointed technical director for the general research organization of Olin Industries, Inc. Dr. Swenson joined the company in 1945 as a consulting chemical engineer and in 1952 became manager of the chemical engineering department of the general research organization. During 1953 he was both manager of the engineering development department and assistant for divisional research. Prior to his association with Olin he was a professor of chemical engineering at Cornell University, and from 1935 to 1938 he had been an engineer for Du Pont.

Bruce F. Harvey, who joined the Jackson Laboratory of Du Pont Co. as a research engineer in 1950, has been made research supervisor at that laboratory. A graduate of the University of British Columbia, Vancouver, British Columbia, Dr. Harvey holds the degree of doctor of philosophy in chemical engineering from the University of Michigan. From 1942 to 1946, he was associated with The Consolidated Mining and Smelting Co. of Trail, B. C.

Donald R. Walton has joined the sales department of Rayonier Inc. as a technical service representative.

Harold M. Belkin has joined the research staff of Standard Oil Co. (Ind.) at Whiting, Ind. He received his undergraduate training at Rensselaer Polytechnic Institute and is a candidate for the Ph.D. degree in chemical engineering from Carnegie Institute of Technology.

Humble Oil & Refining Co., Baytown, Tex., has recently announced the appointments of **Frank J. Spuhler, Jr.** as assistant superintendent of the butadiene and butyl rubber plants operated by that company for the government, and of **R. L. Dockendorff** as assistant department head in charge of the process engineering group in the design department of the engineering division, Baytown refinery.


F. J. Spuhler


R. L. Dockendorff

Dr. Spuhler joined the technical service division at the Baytown refinery in 1939, and in 1941 was assigned to the section responsible for the technical work at Baytown Ordnance Works, the government-owned toluene plant operated during World War II. Since 1944 he has been employed in the polymerization and isobutylene extraction section. More recently he was engaged on a number of training assignments in the refinery proper, returning to the synthetic rubber plants in 1925.

In his new position, Dr. Dockendorff will be in charge of process engineering design on major additions to the Baytown refinery. He joined the company in 1936 serving first in the technical service division, transferring to the engineering division in 1939.

J. Clark Kaskie is now a member of the process investigation group, engineering department, Monsanto Chemical Co., Texas City, Tex. Mr. Kaskie, who has been serving as a supervisor at the John F. Queeny plant, will become supervising engineer for product investigation work on polyethylene. He was first employed by Monsanto in 1941 at the company's Carondelet plant, St. Louis. In 1945 he was transferred to the Clinton Laboratories at Oak Ridge, Tenn., and two years later he moved to the Queeny plant.

John E. Frank is a recent addition to the staff of the Whiting Research Laboratories of Standard Oil Co. (Ind.). Mr. Frank obtained his B.S. degree in chemical engineering at Purdue University and has recently been associated with Phillips Petroleum Co.

(More News About People on page 87)

CLASSIFIED SECTION

SITUATIONS OPEN

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SITUATIONS WANTED

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CHEMICAL ENGINEER—PRODUCTION MANAGEMENT—Age 36. M.Ch.E. Twelve years' experience includes resident manager of alcohol plant; chief engineer of eight-plant organization; assistant to vice president in charge of production. Seeking responsible position in production, management or plant engineering. Box 1-4.

PROJECT ENGINEER—P.E. Presently consultant in plant layout and equipment design. Available on consultant arrangement to firm requiring engineer for project management or assistance in obtaining new work. New York area preferred. Box 2-4.

CHEMICAL ENGINEERING PROFESSOR—Interested in challenging industrial position upon return from abroad. Formerly instructor and assistant professor at leading American schools and industrial consultant. Publications. Ph.D. Honorary societies, fellowships. Age 33, family, veteran. Please answer via air mail. J. M. Geist, Technion, POB 4910, Haifa, Israel.

CHEMICAL ENGINEER—B.S. 1941. Graduate studies. Licensed professional engineer. Age 33. Thirteen years' various experience in operation, administration and most recently, process and project engineering of nitrogenous fertilizer plants this country and abroad. Box 3-4.

ASSISTANT PROFESSOR OF CHEMICAL ENGINEERING—Age 27, married. Presently at Pacific Coast accredited school. Desire academic position preferably in the East. Ph.D., publications, references. One year industrial research, two years teaching. Box 5-4.

RESEARCH DIRECTOR—B.S. in Ch.E., Ph.D. in physical chemistry. Fourteen years teaching and academic research; eleven years industrial research and development. Administrative and technical supervision of research division employing over sixty technical men. Specialized in combustion, explosives, jet propulsion, atomic energy, corrosion, electrochemistry. Publications, patents. Desire challenging position of responsibility in research administration. Box 6-4.

CHEMICAL ENGINEER—M.S. Columbia. Seven years' varied process development experience including technical administration, pilot plant operation and design. Desire position offering responsibility and opportunity for future advancement. Location secondary. Box 7-4.

CHEMICAL ENGINEER—Graduate Lehigh University and Alexander Hamilton Institute. Eleven years' chemical and mechanical "know-how." Proven ability handling technical and personnel problems. Prefer Southeast. Prepared résumé and references on request. Box 8-4.

CHEMICAL ENGINEER—M.S.Ch.E., P.E. Age 34, married. Three years laboratory and pilot plant process development and evaluation. One year production supervision. Eight years process and design engineer for equipment manufacturer with complete responsibility for project completion. Publications. Desire responsible position in process development or design. Box 9-4.

CHEMICAL ENGINEER—B.S.Ch.E. Age 28. Seven years' unusually diversified field and office engineering experience, general chemical plant projects. Economics, process design, administrative experience. Seeking challenging position engineering department, production division or chemical plant. Chicago area. Box 10-4.

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JUNIOR EXECUTIVE—Age 37. Chemical engineering research and development, prominent company. Seek relocation with chemical concern. Desire managerial position, alternatively technical director or administrative assistant. Industrious, excellent personality, record and references. Box 15-4.

CHEMICAL ENGINEER—36. M.Ch.E. Desire manufacturers' representations. Several years of highly successful sales experience with refineries, chemicals, contractors, government agencies, and distributors in New York, New Jersey and Delaware Valley areas. Please state product and proposition in first letter. Box 16-4.

CHEMICAL ENGINEER — B.S.Ch.E. 1942. Business administration (I.C.S.) 1953. Age 32, family. Over nine years' valuable experience in production, development, engineering and administration. Present salary over $6,000. Seek responsible position with a future. Box 17-4.

CHEMICAL (PLANT) ENGINEER—Fourteen years' diversified experience as process, construction and maintenance engineer in organic chemical manufacturing, including fermentation. Excellent procurement experience. Desire management position. Box 18-4.

CHEMICAL ENGINEER — B.S.Ch.E. Fifteen years in organic chemicals including plant and pilot plant design, construction, operation, process development and production. Will relocate—near southern New England preferred. Age 43, married, family. Box 19-4.

CHEMICAL ENGINEER — Ph.D. Thirteen years' experience in research, development, plant operation in petroleum industry and in academic field. Currently engaged in high-level administrative work. Desire highly responsible administrative position with medium-sized company with opportunity to utilize both technical and administrative abilities. Box 20-4.

EXPERIENCED CHEMICAL ENGINEER — Ph.D., P.E. Age 28, married, family. Seven years' experience: research on polymers, ion exchange, electrochemistry, and electric batteries; process development of heavy chemicals and organics with administrative functions. Desire position in development or technical service. Box 21-4.

CHEMICAL ENGINEER—M.Ch.E., P.E. 30. Five years' diversified experience with two instrument manufacturers, specializing in pneumatic and electronic controls. Desire challenging position in development, production or sales requiring experience in instrumentation. Box 22-4.

OPPORTUNITY WANTED—CHEMICAL ENGINEER—Age 30. Ten years' broad experience in petrochemicals and inorganics, process and mechanical development and design, job management, economic evaluation. Only responsible position with advancement opportunities considered. Box 23-4.

CHEMICAL ENGINEER—With fifteen years' experience in organic chemical plant operation. Strong administration background. Available as production superintendent or plant manager. Location unimportant. Box 25-4.

CHEMICAL ENGINEER—Ph.D., P.E. Age 35, veteran, family. Now chemical engineering professor. Seek responsible industrial or research position. Nine years' teaching, industrial, and consulting experience. Broad, sound background. Excellent references. Reply only if you have clear-cut, long-term position, justifying a $10,000-$12,000 salary. Box 26-4.

Nonmembers

ENGINEERING COORDINATOR—Seven years' experience in plant maintenance and engineering supervisory responsibilities. Chemical engineering degree. Age 28. Excellent command of English — both oral and written. Desire position leading to executive level of company in process field. Presently employed. Midwest preferred. Box 24-4.

PEOPLE

(Continued from page 85)

Anton Vittone, Jr. is now plant manager of B. F. Goodrich Chemical Co.'s Avon Lake, Ohio, experimental station. He went to Avon Lake from the Institute, W. Va., man-made rubber plant where he was plant manager. He joined the BFG organization in 1942 as a shift foreman at the GR-S plant in Louisville, Ky., and in 1947 was transferred to the Geon polyvinyl chloride plastic resin plant in the same city as a general foreman. He held various assignments with the company here and abroad before being sent to Institute in 1950 as production manager of the world's largest American rubber plant where he was made plant engineer a year later and in 1952 became plant manager.

Everett C. Gosnell is now serving Ohio Machine and Boiler Co. as chemical engineer. Formerly a chemical engineer in research with the Koppers Co., Pittsburgh, Mr. Gosnell was also with the technical design service division of International Nickel Co., New York, as chemical engineer on corrosion, and was manager of the chemical division of the Lukens Steel Co., Coatesville, Pa. Later he was associated with the Colonial Iron Works of Cleveland as vice-president and manager of its chemical and processing equipment division and with the Centrifix Corp., Cleveland, as manager of sales.

John R. Ryan, technical assistant in the explosives department of the Hercules Powder Co., at the home office in Wilmington since 1951, is now the manager of explosives operation in that department. He joined the company in 1940 as a chemist at the Experimental Station near Wilmington, Del., transferring to the Kenvil, N. J., plant in 1941 and becoming powder laboratory supervisor at the Radford Arsenal, Radford, Va., in 1941. He returned to Kenvil as a dynamite research chemist in 1946 and in 1947 became supervisor of that department at the Carthage, Mo., plant. Three years later Ryan was made technical assistant at Kenvil.

Necrology

C. S. BRYAN

Charles S. Bryan, chief chemist of the Rumford Chemical Works, Rumford, R. I., until his retirement in 1951, died recently. Joining the staff of Rumford in 1928, he was engaged in research and development until 1938 when he was appointed to the position of chief chemist. Mr. Bryan was graduated from Syracuse University in 1903.

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A.I.Ch.E. News And Notes

Washington saw a lengthened Council meeting, stretching from Sunday morning to Tuesday noon...but most of the time was recess.

Idea was to meet again during the Washington meeting, if necessary, to act on revisions of the proposed constitutional amendments should any come out of the business meeting.

A reconvening occurred because at the Monday evening business meeting, one suggestion was carried by the majority... the specification of a minimum number (5) on the nominating committee....

This affected Proposal #3 of the constitutional amendments...and Council quickly agreed to the change as did the members in the business meeting No. 2 held late Tuesday evening.

Other proposals brought forth discussion and dissenting opinions by members... but motions to suggest changes were voted down by majority...Only motion for change which carried concerned the nominating committee as explained above.

Now, as provided in the constitution, the proposals, a ballot, plus Council's recommendation that the changes be voted on favorably, will go to all Active members of the Institute for mail vote.

Council & executive committee completed their regular business in record time.

Liaison members at Council gave summaries of committee work in Chemical Engineering & Accrediting, & Student Chapters Committees (J. H. Rushton reporting)...& Chemical Engineering Projects Committee (J. C. Elgin reporting).

Educational Projects Committee will, during the year, according to Elgin, continue to gather information on films of educational value, will republish its faculty list - an annual event now... it also recommended to Council that "Chemical Engineering Problems," published by the Institute, was still in much demand and should be reissued.

Rushton for the committee on accrediting reported on pending inspections of schools & closer cooperation with E.C.P.D....also that A.I.Ch.E. members are working with the Society for Engineering Education on evaluation of engineering education.

Student Counselor to Lamar State College of Technology, C. E. Huckaba, appointed.

Institute's founding will be celebrated with a national meeting in Philadelphia, June 22-25, 1958...fifty years after its organization in that city.

Other meetings recently approved by Council, both annual...Boston, Dec. 9-12, 1956...& Chicago in 1957.

Council members have a plurality of reports to study not only from A.I.Ch.E. (every committee writes an extensive report of its activities during the year) but also the minutes of Engineers' Joint Council, & the proceedings of E.C.P.D. are distributed to each councilor & demand time & attention.

For instance: On April 6 members of Council are invited to meet in Chicago with boards of other engineering societies for an inspection trip of proposed sites for an engineering center in Chicago.

Whether and when the engineers will find a new home is anybody's guess... three cities making a determined effort to build the center are Chicago, Pittsburgh, & Washington.

New York, site of the present headquarters, has also begun to stir...possible sites are in Washington Square, in the new Columbia Engineering Center, & in the new Coliseum at Columbus Circle.

Space problems plague engineering societies & the present engineering headquarters in 39th Street are inadequate.

A.I.Ch.E. recently signed a five-year lease for more than double its present space (part of it will be subleased for a short period) at 25 West 45th Street in New York.

Space problems of the Institute highlight a spectacular growth period over the past several years.

When S. L. Tyler, now secretary & executive secretary of the Institute, took over in 1937, the Institute had 1,486 members & one other full-time employee (Sophia Sheerin - still with us)...headquarters had two rooms. At that time the Institute, founded in 1908, was twenty-nine years old...its budget amounted to $20,000.

Now, seven years later, its space requirements cover more than 6,000 sq. ft....employees now number 36, its budget is a half million dollars, & membership is close to 14,000...this was a period of outstanding growth & a tribute to the steady development of the Institute under S.L.T.'s guidance.

F.J.V.A.


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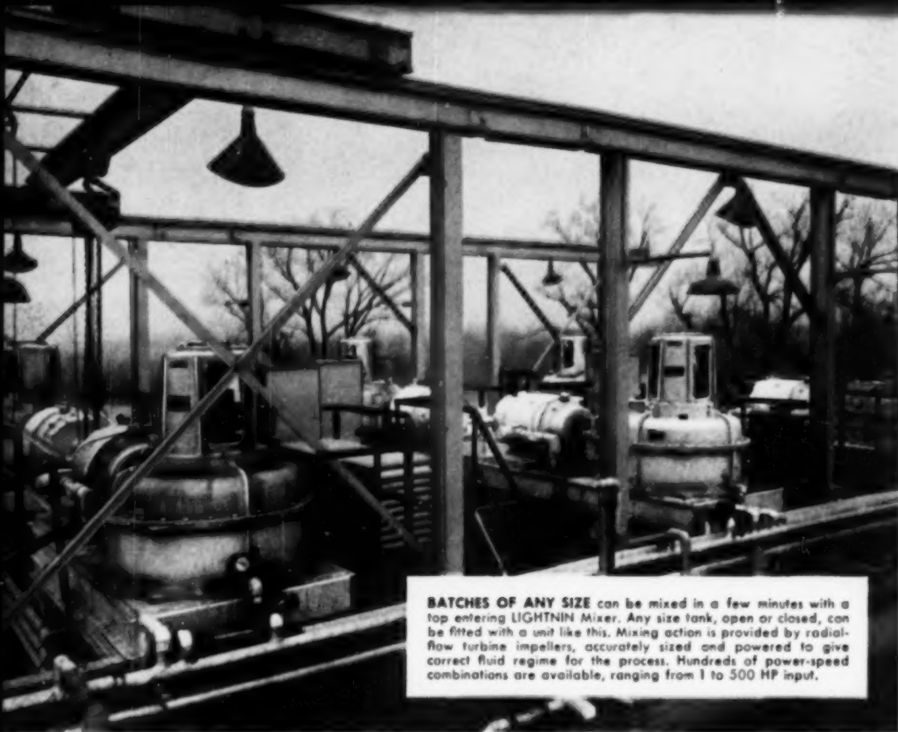

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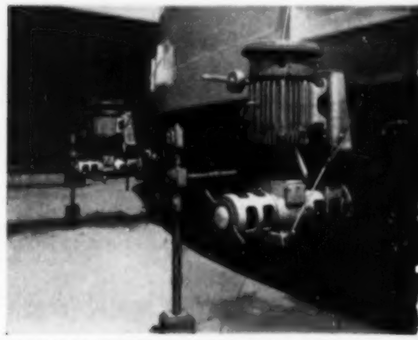

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